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REPORT

ON THE

DANISH OCEANOGRAPHICAL EXPEDITIONS 1908-1910

TO THE

MEDITERRANEAN AND ADJACENT SEAS

PUBLISHED AT THE COST OF THE CARLSBERG FUND

UNDER THE SUPERINTENDENCE OF

JOHS. SCHMIDT, PH. D.

DIRECTOR OF THE CARLSBERG PHYSIOLOGICAL LABORATORY, COPENHAGEN,
MEMBER OF THE DANISH COMMITTEE FOR THE STUDY OF THE SEA,
LEADER OF THE EXPEDITIONS

VOL. I: INTRODUCTION, HYDROGRAPHY, DEPOSITS OF THE SEA-BOTTOM

COPENHAGEN
ANDR. FRED. HØST & SØN
PRINTED BY BIANCO LUNO
1912

J. N. Nielsen phot. *Pacht & Crone, Copenhagen.*

RESEARCH-STEAMER "THOR"
IN RIVER TAGUS AT LISBON.

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CONTENTS.

Page

I. Introduction,
with Pl. I, by JOHS. SCHMIDT 1

II. Hydrography:

1. Hydrographical Observations 53
2. Hydrography of the Mediterranean and adjacent waters, with Pl. II—XI, by J. N. NIELSEN 77
3. Exact determination of the Chlorine in some samples of Seawater from the Mediterranean, by H. BJØRN-ANDERSEN 193
4. Determination of the quantity of Oxygen in Seawater (Methods used), by SVEN PALITZSCH 199
5. The amount of Oxygen in the water of the Mediterranean, with Pl. XII—XVII, by J. P. JACOBSEN 207
6. Measurement of the Hydrogen Ion Concentration in Seawater, with Pl. XVIII—XIX, by SVEN PALITZSCH 237

III. The Deposits of the Sea-Bottom,
with Pl. XX, by O. B. BØGGILD 255

I.

INTRODUCTION

BY

JOHS. SCHMIDT

CONTENTS

page

I. Foreword 3

II. Vessel of the Expeditions, apparatus and methods of working 6

III. Regions investigated and narrative of the Expeditions 14

IV. Material collected by the Expeditions and supplementary information acquired later 22

V. List of the Stations 25

I. Foreword.

The present volume contains the first report on the results of the Danish oceanographical Expeditions to the Mediterranean in the years 1908—1910. These Expeditions were not independent and isolated undertakings, they grew out of and were in every respect a direct continuation of the oceanographical investigations, which my colleagues and I had been carrying out in the North Atlantic Ocean since the year 1903 and the results of which are mainly to be found in the publications of "Kommissionen for Havundersøgelser" of Copenhagen. During this work we paid equal attention to the biological and hydrographical conditions in the sea and year by year it became impressed on me, how the former were dependent on and determined by the latter. For one single group of animals we had endeavoured to ascertain the precise relation of dependence and our investigations over a wide area, which even then reached from the Polar Circle north of Iceland to Spain, had shown to how great an extent the hydrographical factors of temperature and salinity have a determinative influence on the distribution and spawning regions of the different species[1].

Our work on these problems in the North Atlantic during the years 1903—1907 led naturally to the desire, to find an occasion for widening and testing our results in waters which were essentially different from those we had previously investigated. For this purpose no sea near at hand seemed more suited or more inviting than the Mediterranean. Up to that time also the Mediterranean had scarcely been subjected to any thorough investigation of the kind projected and there was, further, the special desire on my part to make an investigation there in the winter time, in order to extend the investigation on the biology of the freshwater eel which I had made in the summers of 1905—1906 in the Atlantic Ocean west of Europe[2]. For such a winter investigation the Mediterranean seemed to me peculiarly well suited, partly because we could rely upon having better weather conditions there than in the open Atlantic and more especially, because we find there in the Straits of Messina the places, made classic by the Italian investigations of Professor Grassi, for the occurrence of the larvae of the eel and its supposed spawning grounds[3].

With these aims in view I applied to the Directors of the Carlsberg Fund in the winter of 1907 and obtained the promise of pecuniary support for such a winter expedition in the Mediterranean. I first of all communicated with various companies in the Mediterranean towns with the object of hiring a steamer, but very soon gave up this plan, as I found a much better way than to use a hired vessel which was not built or arranged for such work. A vessel suited in every respect to the purpose lay already to

[1] Johs. Schmidt: The Distribution of the Pelagic Fry and the Spawning Regions of the Gadoids in the North Atlantic from Iceland to Spain. (Rapports et Procès-Verbaux du Conseil International pour l'Exploration de la mer, Vol. X, No. 4, Copenhague 1909).

[2] Johs. Schmidt: Contribution to the Life-History of the Eel (Anguilla vulgaris Turt.). Rapports et Procès-Verbaux du Conseil International, Vol. V, No. 4, Copenhague 1906 and
id: Remarks on the Metamorphosis and Distribution of the Larvae of the Eel (Anguilla vulgaris Turt.). (Meddelelser fra Kommissionen for Havundersøgelser, Serie Fiskeri. Bind III, No. 3, Copenhagen 1909).

[3] Grassi e Calandruccio: Riproduzione e metamorfosi delle Anguille. (Giornale Italiano di Pesca ed Acquicoltora, No. 7—8, Rome 1897).

hand in the research-steamer "Thor". The "Thor" is specially equipped for oceanographical investigations. It belongs to the Danish Government and is under the control of "Kommisionen for Havundersøgelser", who employ it for carrying out the investigations that fall to Denmark as participator in the International Investigations of the Northern Seas. With this vessel we had carried out the oceanographical investigations in the North Atlantic referred to above.

In the summer of 1908 I made a cruise with the "Thor" to Iceland and the Færoes, but the "Kommissionen for Havundersøgelser" had then no use for the ship until the next spring and there was thus time for an expedition to the Mediterranean in the winter. The Department of Agriculture gave its sanction to the use of the "Thor", free of expense, for such an expedition and also permitted both myself and the regular officers of the crew to take part in the cruise under service conditions. I then applied once more on this basis to the Carlsberg Fund. The latter voted ca. 20,000 Kroner to meet the expenses connected with the fitting out, insurance and management of the "Thor". The Expedition was thus assured and could be carried out for a much less expenditure than probably any other deep-sea expedition of the same duration[1].

On November 13th 1908 the "Thor" left the harbour of Copenhagen, on December 5th it passed Gibraltar, investigations being made on the way, and in the middle of the same month we began work in the Ionian Sea, which I had selected as the principal field of operations with Messina as base.

This plan was disturbed very early, however, by the great Sicilian-Calabrian earthquake of December 28th 1908, which destroyed Messina, and we were obliged to choose a new base. By this time also we had seen that, with the means at our disposal, we could not at this season hope for any greater results in our investigation on the biology of the freshwater eel than we had already attained to in 1906 in the North-East Atlantic. I resolved, therefore, to restrict our work no longer to the Ionian Sea and the Straits of Messina, but to lay all the more weight on our second, main task, and investigate as much of the Mediterranean as was possible with regard to the pelagic animal-life and its dependence on the hydrographical conditions. The results of the hydrographical investigations, which I had made already, contributed also to this change of plan. They seemed to me so exceedingly interesting in themselves, that they acted as a stimulus to continued work in this direction. The rest of our stay in the Mediterranean, in January and February 1909, though often broken by bad weather, was then devoted to investigations over a long series of stations in the western basin. We spent a good deal of time on the work in the Straits of Gibraltar and on both sides of this, as knowledge of the conditions at this entrance to the Mediterranean is of primary importance for the comprehension of the biological and hydrographical conditions in the Mediterranean as a whole. Biological and hydrographical investigations were made at all the more important stations, the latter by myself. As often as possible I corresponded regarding these with Mr. J. N. Nielsen, who had taken part as hydrographer in the Atlantic cruises of the "Thor", but was unfortunately prevented from accompanying me to the Mediterranean. I took a great interest in this hydrographical work, on which more time was spent than was originally intended.

When the "Thor" returned to Copenhagen in the latter half of March 1909, the work of sorting out the biological collections was begun, and the water-samples were first investigated with regard to their chlorine and oxygen contents at the Hydrographical Laboratory and the material then handed over to Mr. Nielsen for further elaboration.

On going through the material for the first time, it proved that our cruise had brought to light

[1] A second and no less important advantage in using the "Thor" was, that we were in a position right from the first day to work with a proved vessel and apparatus and with a fully trained crew. It would be of great advantage, if other countries possessing research-steamers, which like the "Thor" are laid up for a part of the year, would follow this example and use them for scientific expeditions when not required for fishery purposes. In 1910 the Norwegian research-steamer "Michael Sars" was used on a scientific, deep-sea expedition in the Atlantic under the leadership of Dr. Hjort and Sir John Murray.

many things of interest, both in biological and hydrographical regards, and that it would essentially alter the prevailing views on several points. At the same time it became more and more clear, that if we desired to obtain a picture of the oceanography of the Mediterranean in any way complete — and our endeavours were directed naturally to this end — we must undertake another cruise there at a different season of the year. Every one who has attained to more than a mere superficial knowledge of the ordinary oceanographical problems, will also know how uncertain and confused the results often are when obtained from one period of the year only; to use a comparison, it is just as if we had a single, momentary glance at the surface of the sea and from that were obliged to conclude as to its appearance at other times and under other conditions. In addition to this, our winter cruise had been interrupted a good deal by bad weather and the time at our disposal had not permitted us to investigate even the most important parts of this extensive and, in reality, little known sea. For these reasons I came to look upon the winter expedition as a reconnoitring cruise, which could only receive its full and due importance through another expedition in the summer, and my endeavours were now directed to the realisation of this end. No small difficulties arose but were overcome in the end and I was able to carry through my plan with the help of the same institutions as before. The Directors of the Carlsberg Fund voted 14,000 Kroner and a private person gave 10,000 Kroner towards the expenses of the Expedition, and the Department of Agriculture granted the use of the "Thor" under the same conditions as on the First Expedition.

Our Second Expedition in the Mediterranean was carried out during the period from the middle of June to the middle of September in the summer of 1910. This time Mr. Nielsen the hydrographer was able to take part in the Expedition. He had worked up the material of the winter cruise in the meantime and was thus peculiarly well prepared to grapple with the problems, we might hope to solve by this Second Expedition. As on the latter half of the First Expedition our intention was to make biological and hydrographical investigations together at each and every station, but the lines we followed were this time mainly dictated by the hydrographical requirements, which led to our investigations extending over the greater part of the Mediterranean. The Chart of the Stations Pl. I will show, that we were successful in our plans and were able to investigate the principal parts of this great Sea, its western basin and the adjacent parts of the Atlantic even twice over, both on going and returning.

That we have been able to realize our undertaking, is due to the extremely great interest shown in it from all sides from the very beginning. On behalf of the Expedition I would first and foremost tender my most sincere thanks to the Ministry of Agriculture and the Directors of the Carlsberg Fund for the liberality with which vessel and funds were placed at our disposal, and my thanks are no less due to my colleagues of "Kommissionen for Havundersøgelser", without whose assistance the Expeditions could scarcely have been carried out.

I must also gratefully acknowledge the good-will and kindness of the Ministry of Marine and the Directors of our two largest steamship companies, The United Steamship Company, Copenhagen, and The East-Asiatic Company, Copenhagen, who arranged for supplementary investigations and collections being made for us in the Mediterranean and Atlantic.

We have received a great deal of assistance from the Danish consuls in the countries round the Mediterranean, and especially from Dr. H. C. Nissen, the Danish Consul-General in Algiers, who has spared no pains to help us in various ways.

Lastly, I must acknowledge with sincere thanks the sympathy and the direct support, which our work received from the famous Oceanographical Institute in Monaco.

II. Vessel of the Expeditions, apparatus and methods of working.

On an earlier occasion[1] I have given a description of the research-steamer "Thor" and of the methods used on its Atlantic cruises. This description was in Danish and for that reason I may repeat it here with some supplementary information, referring those who are acquainted with Danish to the earlier publication.

Research-steamer "Thor".

This vessel has a gross tonnage of 205 tons (75.6 net) and is of the English steam-trawler type. It was built by Edwards Brothers of North Shields in England and belonged earlier to a fishing company, until it was taken over by the Danish Government and adapted for marine investigations. Since 1903 it has been used in the service of the International Investigations of the Sea under the direction of "Kommissionen for Havundersøgelser".

The length of the "Thor" is 35 m. (115 feet), its greatest breadth (6.5) m. (21 feet) and when the bunkers are full it draws 4.25 m. (14 feet) at the stern and 2.25 m. (8 feet) forward. It is provided with triple expansion engines, which develop 325 indicated (52 nominal) horse-power and give the vessel a speed of 8 miles per hour with a coal consumption of ca. 5 tons in the 24 hours. The engines were built in South Shields by G. T. Grey.

Below deck forward is the forecastle with berths for 10 men of the crew, then comes the store-room for the fishing-apparatus and collections etc. The mess and cabins of the scientific staff lie amidships, behind these are the coal-bunkers, which hold 70 tons of coal, the engines and lastly, right aft, the mess and cabins of the officers.

The deck-house is about 20 m. long; the front part forms the laboratory, the middle part is the engine-room and the aft part contains the galley and first-mate's cabin. with access to the engine-room and the companion down to the mess. The steering-house with chart-room is above the front part of the deck-house over the laboratory.

A life-boat is swung on each side on davits behind the funnel. The one is a motor-boat 6 m. long by 1.9 m. broad, provided with an "Alpha" petroleum motor of 2½ horse-power. This is much used in fishing with small apparatus in shallow water.

The front part of the deck-house, which as mentioned is fitted up as the laboratory, is 5.4 m. long, 2.9 m. broad and 2.10 m. high. The laboratory is arranged like an ordinary scientific laboratory with the changes rendered necessary by the conditions on board. It is lighted on each side by 5 large windows, which can be closed by iron deadlights in heavy weather, and the whole is fitted with electric light. The starboard side of the laboratory is used for the biological, the port side for the hydrographical work.

The installation of the different apparatus used can be seen from the plan, fig. 1. A is the trawl-winch for heaving up the larger apparatus, either over the davit on the starboard side (B) or over the davit aft on the port side (C). D is a small steam-winch, which is used for heaving up the lead or the water-bottles over the davit forward on the port side (E^1), or for heaving in the plankton-net after vertical hauls over the davit further aft (E^2). The davit amidships (F) on the port side is used for hauling up the lead, water-bottle or plankton-net from shallow depths with the hand. At (G) forward on the port side is fixed a Lucas sounding-machine. This is only used as a rule over great depths to obtain exact soundings.

The trawl-winch (A), which hauls in the larger fishing-apparatus, is placed before the foremast. It is a strong winch of ca. 9 horse-power of the kind used on steam-trawlers, and was built by Good and Menzies, Hull, England. It has two separate drums 1.2 m. in diameter, which can be worked independently of one another. Each drum can carry ca. 2000 m. wire of 3.75 cm. (1½ inches) in circumference. The bearing-power of the winch is 4½ tons.

[1] Fiskeriundersøgelser ved Island og Færøerne i Sommeren 1903 (Skrifter udgivne af Kommissionen for Havundersøgelser, Nr. 1, København, 1904).

Arrangement of the apparatus for horizontal hauls.

The larger fishing apparatus, which are worked horizontally, are carried out over one of the fishing davits. The heaviest of these (fig. 1, B) is fixed on the starboard side and is used for apparatus which keep open in fishing by means of otter-boards (otter trawl and young-fish trawl). The arrangement is seen from fig. 2. The wire (B) leads from the starboard drum of the winch (A) to the horizontal block C^1 in front of the laboratory and from there to the vertical block D which hangs from a strong, spiral spring of steel round the davit, the accumulator (E), and is thus movable up and down with the closing and opening of the spring. Further, the block D with the spring can be swung horizontally round the davit. From D the warp passes upwards and round a second vertical block (F), which can only be partly seen in the figure and which is also free to swing in a horizontal direction, and from this the warp runs overboard. F is a so-called meter-wheel, that is to say, it is provided with a registering apparatus (H) so constructed, that the number of times the wheel has gone round is marked by the position of the different hands and the length of wire out can thus be read off directly. The shortness of the davit (2 m.) and the accumulator on it make the movements of the vessel in a seaway less felt by the apparatus during trawling or on heaving in. Further, when the trawl is working on the bottom in shallow water, the presence of the accumulator enables us to see, whether the apparatus is travelling evenly over the ground or not, as the least obstruction on the bottom naturally makes the spring close up.

The otter-trawl used on the "Thor" differs only in its smaller size (50-foot head-rope) from the ordinary otter-trawls used by steam-trawlers. The trawl is a wide-meshed, very pointed net with short wings and longer top-part (square) than under-part (belly); it is figured in fig. 3. Round the hindmost part, the so-called cod-end, is fastened a net with finer meshes than the rest of the trawl (see fig. 3, f); its mesh is 2.5 cm. when extended. In this way a number of the smaller animals, which would otherwise escape through the meshes of the ordinary trawl, are retained and caught. At each side of the trawl the wings are fastened to an otter-board (one of these is shown at B in fig. 4, p. 9). The boards are made of thick planks of pine (length 1.9 m., height 0.8 m.) with two long iron bolts through them; below they have heavy iron keels. The towing warps are attached by means of a shackle a little in front of the middle of the board. When the apparatus is towed through the water, the boards stand upright and tend to spread outwards and forwards owing to the trawl-warps being attached in front of their centre, and the net is in this way stretched out and held open. Where the professional trawlers use two warps, one for each board, and each board is hauled up to its own davit, one forward and one aft, the

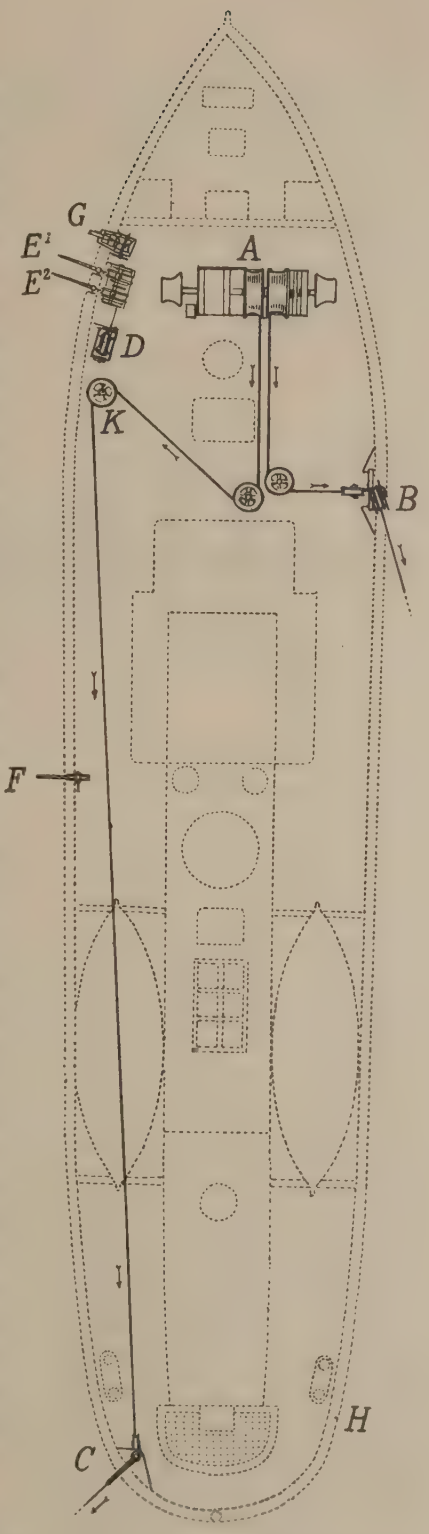

Fig. 1. Plan of the "Thor", showing the installation of the different apparatus.
A Trawl winch; the wire follows the direction of the arrows to the davits B and C, which are used for horizontal hauls. D is a small steam winch used for hauling in apparatus employed for vertical hauls over the davits E^1 and E^2, and for Lucas' Sounding-Machine (G). F is a davit used for vertical hauls with hand-power.

trawl-warp of the "Thor" is single in the manner used by C. G. Joh. Petersen (Report of the Danish Biological Station, VIII and XI, 1898 and 1902). Each board has its separate bridle 65 m. long and the two bridles form a crow-foot where they are shackled on to the warp. When the trawl is in the water, the warp is brought up aft into a snatch-block at the side of the ship (at H in fig. 1) so as to prevent it getting into the screw. Both boards are hauled up to the davit with the accumulator (fig. 2). This arrangement greatly lightens the work of manœuvring, not least in deep water or in bad weather.

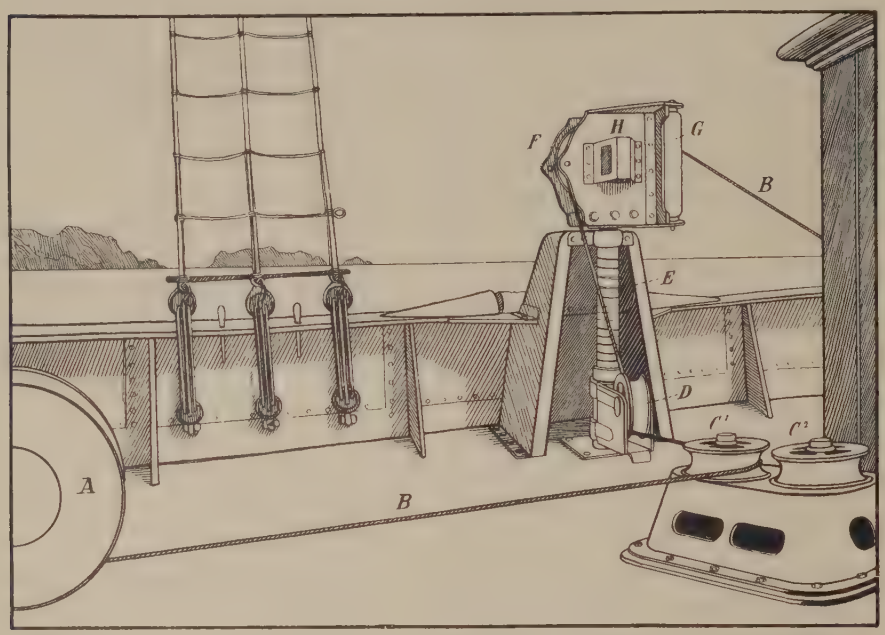

Fig. 2. Starboard davit for horizontal hauls with large apparatus (otter-trawl and young-fish-trawl).

The young-fish trawl constructed by C. G. J. Petersen (fig. 4) is worked in a similar manner and over the same davit. The model of young-fish trawl we have most frequently used, is a 7 m. long net with the opening 2 m. in diameter (a second model is 8.5 m. long and 3.3 m. in diameter). It is made of the so-called "stramin",[1] a coarse canvas made of hemp, which has ca. 20 threads to 3 cm., and is so compact and dense that it retains even the smallest fry of fishes. The mouth of the net is attached to two poles $1^1/_2$ m. long and 8 cm. thick, which stand vertically during trawling and thus make the opening rectangular. By way of support strings are fastened along the four edges of the net, from the mouth to some way behind the middle. The net is open at the end and simply closed by a piece of cord. To the ends of each pole are attached two ropes 6—7 m. long which pass to the board, one on each side, and just as with the otter-trawl the boards, which are here smaller and lighter (length 1.2 m., height 0.7 m.), keep the net stretched out in the water when fishing, though the upper and under parts are not quite taut. The young-fish trawl can be used both on the bottom and pelagically; it is best suited to the latter however and has been greatly used in this manner on our Mediterranean cruises. A great advantage is that it is easy to manœuvre with and can be used even in a high sea.

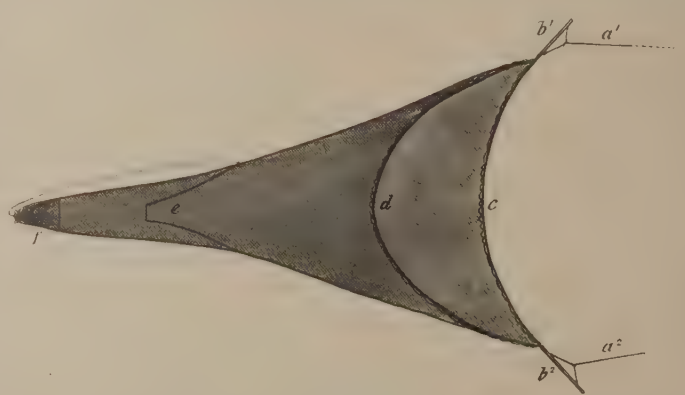

Fig. 3. Otter-trawl of the "Thor", stretched out, with boards and a part of the bridles forming the crow-foot, seen from below. a^1 and a^2 the bridles of the crow-foot, b^1 and b^2 the boards. c head-rope, d ground-rope, f fine-meshed net round the cod-end, which retains the smaller animals.

Various dredges are used over the same davit as the otter-trawl and the young-fish trawl, especially a large model with rectangular frame-work (1.17 by 0.27 m. opening) and that used by S. A. S. Prince Albert of Monaco and called by us

[1] The "stramin" is obtained from Utzon's net manufactory, Copenhagen, and costs 2.25 Kr. per meter.

the "Monaco trawl" (Bulletin de l' Institut Océanographique de Monaco, No. 162, p. 28, 1910). Our model had a length of 6 m. and its opening was 1.70 by 0.56 m. The meshes are 3 cm. when extended.

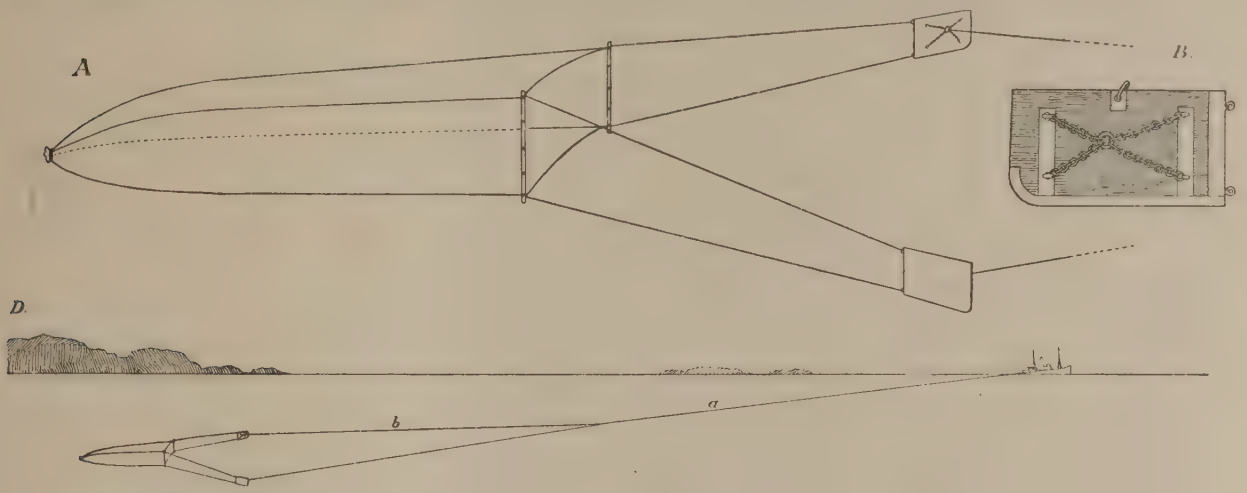

Fig. 4. Petersen's Young-fish trawl. A the bag of the net with poles, to which are attached the ropes passing to the boards. In front (to the right in the figure) is seen a part of the bridles of the crow-foot, which are of steel-wire. B the right board, seen from the inner side. D Schematic picture of the young-fish trawl at work.

All the apparatus mentioned were towed by means of a steel-warp 3.75 cm. ($1^1/_2$ in.) in circumference with a breaking-strain of $7^1/_2$ tons. Of this we had about 2000 m. rolled round the starboard drum of the winch.

The apparatus hitherto mentioned are worked from the starboard side. On the port side is a different set of apparatus, used for fishing in very great depths with dredges and with large pelagic nets, e. g. ring-trawl, which will be described below. The towing-warp, which is of steel-wire 0.7 cm.(0.28 in.) in diameter with a breaking strain of 2.6 tons, has a length of 5000 m. and is rolled round the port drum of the winch. Like all the other trawl-wire used on the "Thor" it was obtained from R. J. Hewitt, Hull, England and has proved to be excellent in all regards. As will be seen from the plan fig. I, the wire passes from the port drum of the winch to the horizontal block in front of the middle of the laboratory (C^2 in fig. 2), from there almost at right angles to the horizontal block on the port side (K in fig. 1) and then aft to the davit near the stern on the port side (fig. 5. and C in fig. 1). The latter davit is 1.75 m. high and bent; as the figure shows, it has 3 blocks and an accumulator which can be turned round its vertical axis. The wire first passes round the lowermost block, which is fastened to the accumulator and with this can be swung horizontally round the davit independently of the latter. From the first the wire passes to the second block, which is fastened by a short axle to the davit and moves with this, and from there lastly to the uppermost block, on which there is a registering apparatus, and from there overboard.

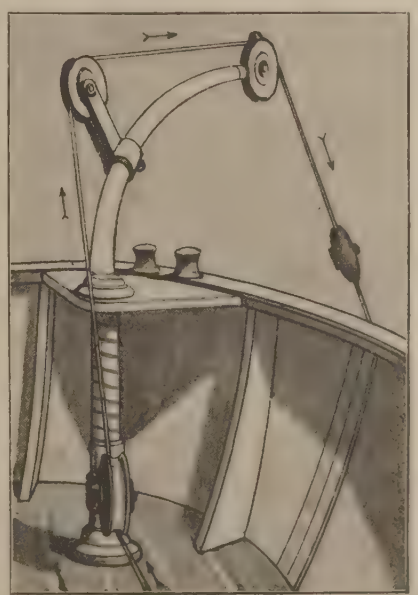

Fig. 5. Davit aft on the port side for horizontal hauls in great depths.

The installation described is used especially for the ring-trawl, an apparatus for pelagic fishing in very great depths, when it is towed horizontally after the ship and is closed before hauling in. The ring-trawl is shown open and closed in fig. 6. The actual fishing part is a net of stramin, of the same dimensions as in the young-fish trawl, so that the same net can be used in both apparatus. The net is fastened here to an iron ring, 2 m. in diameter with a weight of ca. 35 kilos. The ring is not all one piece but is composed of two semicircular parts connected by joints and can thus

be folded up. The apparatus is towed in a double crowfoot with bridles 2 m. long, of the same kind of wire as the warp. The arms of the one crowfoot (a) are attached at the middle of the two semicircular halves of the ring and the upper end is fastened to the underside of a heavy, metal slip-apparatus of NANSEN's model, which is shackled on to the warp. The arms of the second crowfoot (b) are made fast at the two joints of the ring and the upper end hangs loose in the movable hook of the slip-apparatus. The sinker used in releasing the slip-fapparatus is of iron and 10 kilos. in weight, made hollow to reduce friction on its descent down the sloping warp. When the sinker strikes on the slip-apparatus, the hook supporting the one crowfoot falls down and sets free the bridles, with the result that the ring folds together and the net is closed. The ring-trawl can also be used in a smaller size, the diameter of the ring being 1.3 m. The apparatus has the same fishing qualities as a young-fish trawl of the same size.

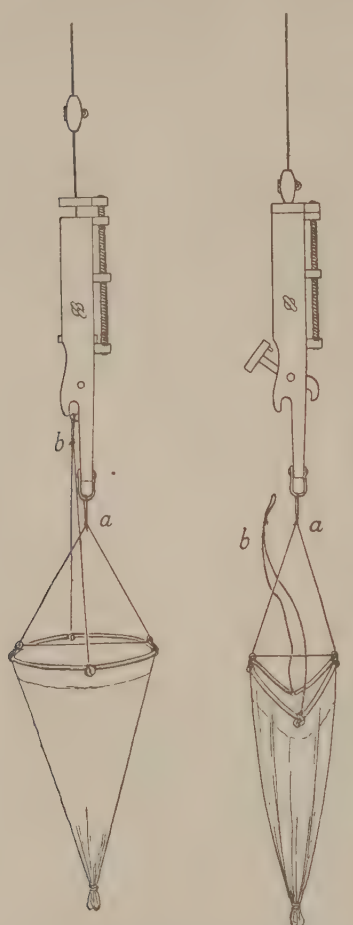

Fig. 6. Ring-trawl of the "Thor" for horizontal hauls in great depths, open and half-closed, with closing-apparatus of Nansen's pattern. a the fixed crow-foot, b the loose crow-foot which hangs in the movable hook of the slip-apparatus when towing the apparatus through the water, but which slips from the hook when the sinker is sent down and the net is then closed. The apparatus is drawn hanging vertically and the nets are greatly reduced in proportion to the slip-apparatus.

My reason for introducing this apparatus on the Mediterranean cruises of the "Thor", was that it offered certain advantages over the earlier. When the apparatus is closed, it cannot fish in the upper layers on being hauled in and there is less strain on the winch, warp and apparatus. For the same reason we can use a thinner warp and thus have room for a greater length of wire on the drum. We could thus fish in greater depths, which is of special importance in the deep Atlantic and Mediterranean. In the beginning I had the iron rings made in one piece; the sensible construction, with two semicircular halves folding together, which has come well out of its trials, is due to Capt. G. HANSEN of the "Thor".

In addition to the ring-trawl, the port side was also used often for various bottom-dredges, both the above- mentioned rectangular model and a second, smaller dredge with triangular opening, in which the sides were 0.45 m. in length. The material of the dredges was of stramin and several bottom-samples were brought up in them.

In fishing for surface-plankton and the eggs of fishes pelagic nets 1m. in diameter and of silk-gauze No. 3 were put out over the stern of the ship, when the larger, pelagic apparatus were being used. Sometimes they were towed in great depths attached to the trawl-wire. Other smaller and finer silk-nets were also used for the collection of plankton. Their dimensions and construction etc. can be seen from the list, p. 25, of the apparatus used in the investigations.

Arrangement of the apparatus for vertical hauls.

The preceding account referred to the various apparatus used in making horizontal hauls. In addition, there is a special arrangement forwards on the port side (see the plan, fig. 1 and fig. 7), which is used for paying out and heaving in the apparatus fishing vertically through the water. As can be seen from the figure, 7, this consists of a small winch (A) of one-half horse-power, driving 2 drums of ca. 0.7 m. in diameter (B) round which is wound a steel wire of 3 m.' in diameter[1]. Opposite each drum on the bulwarks is a davit 2.9 m. high, from which there hangs a steel-spring accumulator of a similar kind to those already described. On the accumulator is suspended a block (1) and the davit bears three other blocks, suspended vertically; the lowermost and largest (2) is provided with the registering apparatus, the middle one (3) is fixed to the davit at the angle and the uppermost (4) is hung on the highest point of the davit. The figure shows how the wire from the drum passes to block 1 and then round the other blocks in turn and overboard.

In general the arrangement described is only used whilst working in fairly deep water. For use

[1] Obtained from Felten & Guilleaume, Muelheim, Germany; breaking-strain 1—1½ tons.

in quite shallow depths there is a smaller davit (quite 2 m. high; fig. 8) midships on the port side, on which there is a flat drum to be worked with the hand. The wire goes from the drum to the block with the registering apparatus on the highest point of the davit and then overboard.

The installations just mentioned for vertical hauls are used for making soundings, paying out and hauling in the hydrographical apparatus (water-bottles and reversible thermometers) and plankton-nets, with which larger or smaller, vertical columns of water are fished through.

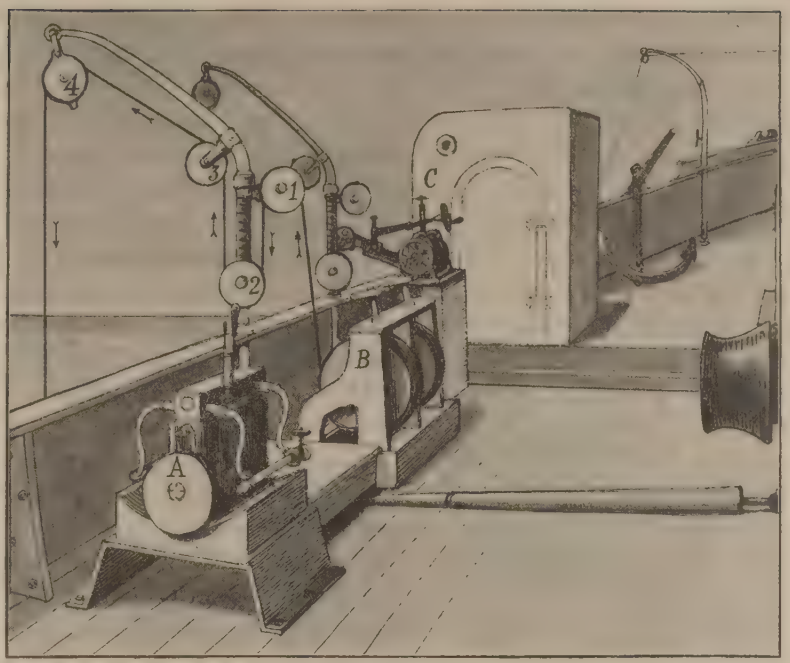

Fig. 7. The two davits forward on the port side for vertical hauls with steam-power. A Small steam-winch which drives the drum B, on which the wire is rolled. C the position of the Lucas' Sounding-Machine.

In shallow water soundings were made as a rule either with a hand-lead or over the davit in fig. 8, the lead being pulled in by means of the hand-drum. In the case of greater depths, down to ca. 2000 m., the davit in fig. 7 was used, and the lead hauled up by the small steam-winch. In this way, if a heavy lead of 20 kilos. is used, good soundings can generally be made in calm weather down to depths of ca. 2000 m., as there is a distinct jerk on the wire when the lead strikes the bottom. At greater depths the result is uncertain, as the great length of wire payed out weighs so much in proportion to the lead, and when the ship heels over in a high sea especially, reliable soundings cannot be made in this way in more than ca. 1500 m. Under such conditions we use a Lucas' sounding-machine, large model, supplied by the "Telegraph Construction and Maintenance Company" London, the installation of which can be seen from the fig. 7. As the lead-line here is quite thin piano-wire (ca. 1 mm. in diameter), its weight is not out of proportion to the weight of the lead; further, when the lead strikes the bottom, it is set free and remains there. This causes such an appreciable break in the speed with which the wire is running out, that there can be no doubt when the bottom is reached. In making soundings with Lucas' machine we use as leads old cannon-balls of ca. 10 kilos. in weight, which are set free by means of a simple mechanism devised by Capt. G. Hansen of the "Thor" and represented in fig. 9. The balls are hung in a piece of thin string with a double eye at the end (a). This is not made fast directly to the sounding-wire (c), but a second piece of thin string (b) is inserted between them, ending in a small hook, just large enough to go into the eye in the string suspending the ball. As long as the latter is travelling down through the water and keep-

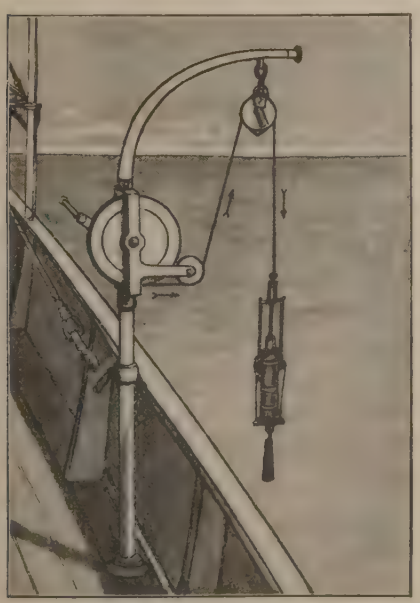

Fig. 8. Davit amidships on the port side for vertical hauls and hauling in by hand. A water-bottle is suspended on the wire.

ing the wire and pieces of string taut, the hook cannot fall out, but this happens at the moment when the ball touches the bottom and the strain is taken off the line.

For the water-samples from deep water we always used the PETTERSSON-NANSEN water-bottle, of which we had two models, the one with a propeller for closing, the other closing by means of a sinker. Further, reversible thermometers were used in connection with the water-bottle, fastened on the wire suspending the latter. Regarding the hydrographical instruments and the mode of their use, reference may be made to MR. J. N. NIELSEN's paper in the present Volume p. 105 et seq.

On the summer cruise some investigations were made with the purpose of determining the relative transparency of the water. For this a circular, white disc of 15 cm. in diameter was used, attached to a lead-line and sunk down in the water until it could just be detected and the depth then noted. The method of procedure has been described earlier by DR. OSTENFELD (Report of the Danish Biological Station, XVI, 1908), who was himself on board the "Thor" and carried out these investigations.

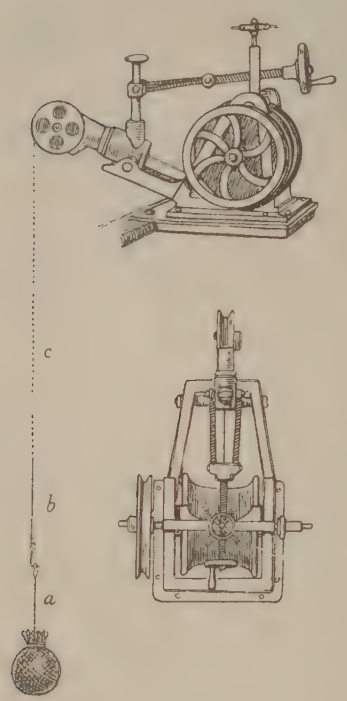

Fig. 9. Lucas' Sounding-Machine with lead and slip-apparatus.

For the vertical plankton hauls we also used, in addition to the open silk-nets which were let down to the desired depth and drawn up open, the closing nets of the NANSEN[1] and APSTEIN[2] pattern, chiefly the former. As the construction of these has been described in the literature and is well-known, they need not be discussed in detail here, but with regard to the dimensions as also to the other plankton apparatus used on the Expeditions, reference may be made to the list of apparatus p. 25.

Of the smallest kind of plankton, the so-called nanoplankton, which goes through the meshes of the ordinary silk-nets, we obtained some samples by filtering 10 bucketfuls of water through a net of taffeta, a specially dense kind of silk. Similarly, a LOHMANN's centrifuge worked by hand was used for centrifuging and concentrating the plankton.

In addition to the apparatus mentioned we also used long-lines, which were set out over the stern of the ship and brought up by means of a hauling machine on the port side, of the same kind as is used on steam-liners. The hooks used were halibut and cod hooks. When at anchor the motor-boat of the "Thor" was often used for fishing in shallow water, for example, with the same dredges as used from the ship and with small hand-dredges intended for the collection of marine algae. Further, at several anchoring places we used a Danish eel hand-seine, which was dragged over the bottom in shallow water by hand. This seine has a length of 47 m. with a seize of mesh in the bight of quite 1 cm., in the wings of quite 2½ cm., extended, and is excellently well-suited to the capture of small fish. Lastly, our list of the apparatus used on the Expeditions comes to an end with the mention of a shrimp-net of stramin, which was sometimes employed in wading from the beach for the capture of various small fishes etc.

Methods of working.

With regard to the work done at the different "stations", reference may be made to the complete record of the investigations contained in this Volume. As will be seen from this, the work at the different stations was of different kinds. The method of procedure at the deep-water sta-

[1] Duc d'Orléans: Croisière Océanographique dans la Mer du Grönland en 1905, Bruxelles, 1907, p. 121.

[2] Apstein: Das Süsswasserplankton, Kiel & Leipzig, 1896, p. 34—37.

tions was as a rule the following. The sailing of the ship was as far as possible arranged so that the hydrographical work could be done in the day-time, the pelagic hauls at night; the latter arrangement was based on our earlier experience in the Atlantic, when we had seen on manifold occasions that far more was taken in the pelagic apparatus at night-time than in the day. When we had arrived at a station, the depth and nature of the bottom were first determined by means of the lead. Then a dredge was put out, either over the starboard or port davit, and this dredge was allowed to stay out during the whole time the hydrographical or vertical plankton investigations were in progress. The use of the dredge in this way was suggested by Mr. E. W. L. Holt of Dublin, who has practised it on the cruises of the Irish research-steamer "Helga", and I can recommend the method as very practical and useful. The vessel drifts less during the hydrographical work, as the dredge acts as an anchor and the time used for the hydrographical work is also usefully spent in another way. The hydrographical work consisted in taking a series of water-samples from different depths, recording the temperature of each, determination of the hydrogen-ion concentration and preservation of water from each sample for the determination of the amount of chlorine and oxygen later. The water-samples from very great depths were always taken up over the davit in fig. 7, but at the same time samples were often taken by hand from less depths over the davit in fig. 8. When vertical plankton hauls were to be made, this was done as a rule immediately after the hydrographical work, sometimes partly along with this, for example from the davit in fig. 8, whilst the hydrographical work was in progress from the davit F (see plan fig. 1).

After this the dredge was hauled up and the young-fish trawl or ring-trawl set out and towed after the ship for a shorter or longer time, usually $^1/_2$ to 1 hour, the ship sailing about 2 knots in the hour. The general arrangement in this case was to take the hauls in the surface layers as far as possible in the night-time, when better results are obtained than in the day. When great depths had to be fished in, this was done as the time suited, whether in the night-time or in the day. The depths at which hauls were made, varied with the stations and according to the distribution of temperature found, but in general 25, 65, 300, 600 and 1000 m. of wire were let out, also according to circumstances 2000—4500 m. of wire. Whilst the young-fish trawl was used as a rule with no more than 200 m. wire, the ring-trawl was used at still greater depths. It is very difficult, not to say impossible to indicate exactly the depth at which the apparatus has been fishing with a given length of wire out, as the depth depends on several factors, which cannot all be determined with certainty. When not too much wire was out I have made a series of experiments by attaching to the pole of the young-fish trawl a Clausen's bathymeter[1], which registers the maximum depth fished in by the apparatus and can be used in depths down to 500 m. These experiments were carried out in the Skager Rak in the summer of 1907 in calm weather and it proved, that the depth in which the young-fish trawl worked with a given length of wire, was extremely dependent on the number of turns of the screw, that is, on the speed of the ship, but in general, when the speed was 2 knots per hour, we could reckon upon the apparatus fishing at a depth which was somewhat greater than half the length of wire out.

It may be remarked, that an apparatus such as the young-fish trawl, which is open when let down and hauled in, will also fish on the way up, so that the main material from deep water, in which the apparatus has fished, will be mixed to some extent with forms belonging to the upper layers passed through by the trawl on hauling in. This fact, which does not apply or only to a less degree to the ring-trawl, which is closed on hauling it in, might seem to vitiate to a great extent the estimate of the depth at which the organisms contained in the haul were really captured. From many years' experience however, I think I may safely say, that the danger of an erroneous estimate is not very great; when we compare the contents of a haul at great depths with those of the hauls in the higher layers at the same

[1] Clausen's bathymeter is sold by the firm Cornelius Knudsen of Copenhagen. It goes under the name of Capt. C. Clausen's Control-Sea-Sounder and costs 75 Kroner without lead.

station, we obtain a good impression of the animals which might be mixed in the deep hauls as the result of the apparatus passing through the upper layers. Further, the amount of the mixed material from the upper layers will be very small in proportion to the main material from the deep water, especially when the hauls in the latter have been of considerable duration, and this was practically always the case with our deep hauls.

At the same time as the young-fish trawl or ring-trawl was being used, hauls were made with silk-nets of various fineness for the collection of plankton. These nets were set out at the stern of the ship and were generally kept in the water for 5 to 10 minutes. Further, other plankton nets were often used in the deeper layers, attached to the crowfoot of the young-fish trawl or to the warp. When the apparatus was hauled in, the pelagic contents were subjected to a preliminary examination, the fish-eggs put aside to hatch out and the quantity noted down as well as the principal forms of the haul. The contents of the young-fish trawl were as a rule emptied into a large zinc bath with water, to which was added a little strong formaline. The contents were then allowed to stand for some time before filtering and preserving in the different bottles and jars. In this way the more delicate organisms were better preserved than if the contents of the haul were at once emptied into the bottles. As preserving liquid we used mostly formaline diluted with seawater. For the bottom-samples and the microplankton, however, alcohol was always used, and this was also the case for preserving various larger plankton organisms, which were at once sorted out from the rest of the material, e. g. Pteropods and Crustacea which do not preserve well in formaline.

The pelagic investigations were everywhere considered our main work and were undertaken at all stations, just a few anchoring stations excepted. Sometimes the work at a station was concluded by making one or two hauls with the bottom-dredges or Monaco-trawl. The otter-trawl was not used in the Mediterranean though at times in the Atlantic. I should like to have had more opportunity for using the otter-trawl, but there was absolutely no time for this, as our aim was to carry through a pelagic investigation over the greater part of the Mediterranean.

III. Regions investigated and general account of the Expeditions.

Boundaries of the regions investigated.

The regions investigated by the Expeditions were first and foremost the Mediterranean, then also the adjacent parts of the Atlantic, the Sea of Marmora and the Black Sea (compare the Chart, p. 15).

The Mediterranean is taken here as the whole of the sea lying within the Straits of Gibraltar and outside the Dardanelles. As the different parts of this Sea often go by different names on charts and in descriptions, it is advisable and convenient to state here the names which are used in this Report and noted on the Chart fig. 10. No claim is made that the names used are better or more correct than those found in other descriptions of the Mediterranean; they are simply put forward and made definite, in order that there may be uniformity in the different parts of the Report.

The Mediterranean is divided by nature into two main portions, the western and the eastern basin, separated by Italy — Sicily and the submarine ridge between Sicily and Tunis, where there is only a narrow channel with depths as great as 300—400 meters.

The western basin consists of the Tyrrhenian Sea and the Balearic Sea with its border-regions, of which we may mention the Alboran Sea between the south coast of Spain and Morocco, the Catalonian Sea east of Spain, Gulf of Lyons and to the north-east the Ligurian Sea. The greater part of the western basin has a depth of between 2000 and 3000 m. Depths of over 3000 m. but not reaching to 4000 m. are

found in the whole of the centre of the Tyrrhenian Sea, whilst in the Balearic Sea we only find areas between the Balearic Isles and Sardinia which have over 3000 m. The principal line of connection between the Tyrrhenian and Balearic Seas is the channel between Sardinia and Sicily, where there are depths between 1000 and 2000 m. A second connection is the narrow channel between Corsica and Capraja, where we find depths of about 400 m. On the other hand, the depth in the Straits of Bonifacio between Corsica and Sardinia is everywhere less than 200 m.

The central part of the eastern basin is the Ionian Sea, over the most of which we find depths greater than 2000 m. Towards the S. W. and S. the Ionian Sea merges into the shallow Sidra Sea, towards the N. into the Adriatic, which is also shallow. As the eastern boundary of the Ionian Sea we take a line

Fig. 10. Boundaries of the regions investigated.

between Barka and the S. W. point of Crete, to the east of which we call the remaining part of the Mediterranean the Levant, with the limitation that the portion of the sea, which is bounded in the S. by Morea, Crete, Scarpanto, Rhodes and Asia Minor and in the N. by the Dardanelles towards the Sea of Marmora, is called the Aegean Sea. The greatest depths of the Mediterranean are found in the eastern basin, especially in the Ionian Sea, where depths of over 4000 m. occur and where the whole of the central region has depths over 3000 m., whilst such depths only occur sporadically in the Levant over smaller areas, e. g. N. of the westernmost part of Egypt and S. E. of Rhodes. The Aegean archipelago in general has depths less than 1000 m., only in a small area not investigated by us to the N. of Crete the depths amount to a little over 2000 m.

It is a characteristic feature of the Mediterranean, that such a large part of its area is very deep. Close to the coast even we meet already the 2000 m. curve, and large areas with depths of less than 200 m.,

such as we find for example in the North Sea, only occur at two places, in the western part of the Sidra Sea and in the Adriatic. Neither of these shallow areas have been investigated by the "Thor", as coastal investigations lay outside the province we had mapped out for ourselves in the Mediterranean.

In the Sea of Marmora the greatest depths lie between 1000 and 2000 m. and in the Black Sea at ca. 2200 m. At the Straits of Gibraltar the Mediterranean joins on to the Atlantic. Towards the latter we mark off the Straits of Gibraltar by a line drawn between Cape Trafalgar and Cape Spartel, towards the Mediterranean by a line from Gibraltar (Europa Point) to Ceuta.

Of the places in the Atlantic investigated by us in 1908—1910 we may note Cadiz Bay, between Gibraltar and Cape St. Vincent, and the Bay of Biscay, by which we understand the water between the north coast of Spain and the latitude of Ushant. The English Channel is bounded in the east by a line from Dover to Cap Grisnez and in the west by a line from Lands End to Ushant.

Narrative of the Expeditions in 1908—09 and 1910.

The personnel on the Mediterranean Expeditions was for a great part the same as on the earlier cruises with the "Thor" in the Atlantic. In addition to the leader of the Expeditions the scientific staff of the "Thor" consisted of the following; on the winter cruise the planktologist Dr. Ove Paulsen, assistant at the Botanical Museum, Copenhagen, and Dr. M. Lerche, reserve-surgeon in the Danish Navy; on the summer cruise the hydrographer Mr. J. N. Nielsen, Meteorological Institute, Copenhagen, the planktologist Dr. H. C. Ostenfeld, inspector at the Botanical Museum, Copenhagen, and the chemist Mr. S. Palitzsch, assistant at the Carlsberg Laboratory, Copenhagen. The navigator on both cruises was Capt. G. Hansen, who has been connected with the "Thor" since 1904, and the remaining crew consisted of 13 men.

Winter Expedition of 1908—1909.

The "Thor" left Copenhagen on November 13th 1908. We passed Gibraltar on the way out on December 5th 1908 and on the way home on February 21st 1909, so that our sojourn in the Mediterranean lasted about two and a half months. Investigations were carried out along the route from Copenhagen to Gibraltar; from there we proceeded to Algiers, where coal was taken in, and then on to Messina, which was intended to be the starting-point for the investigations in the Ionian Sea. These were begun on December 15th and continued in the following week there and in the Adriatic, but they were brought to a conclusion sooner than intended. Christmas week was spent in Piraeus after passing through the Corinth Canal, and from Piraeus small excursions were made to the neighbouring waters. From Greece we returned to our base at Messina, which in the meanwhile had been destroyed by the great earthquake of December 28th 1908. We arrived at Messina on January 5th 1909 and after staying 3 days left the Straits of Messina on our way northwards, to make investigations in the Tyrrhenian Sea,

The greater part of January was devoted to this Sea, though bad weather often interfered with the work. From the 8th to the 15th of January the "Thor" lay in the harbour of Naples for cleaning of the boilers and general overhaul. We then proceeded with our work in the northern part of the Tyrrhenian Sea and in the Ligurian Sea with Mentone as base. It was my intention thereafter to go southwards to the African coast west of Corsica and Sardinia, but unfortunately we only succeeded in taking two stations west of Corsica, when one of the severe storms from the W. by N., so common in this part of the Mediterranean at this time of year, set in on the 31st of January. Instead of wasting time in the open sea, waiting for an improvement in the weather, we went through the Straits of Bonifacio back to the Tyrrhenian Sea and sought for shelter along the lea of Sardinia, where at one time we lay at anchor in Piras Bay on the south-east corner of the island. As the weather improved we set off southwards, intending to make a hydrographical section of the waters between Sardinia and Tunis. Two stations were taken

and then the weather broke down again and on February 3rd we were obliged to shelter under the small island Galita off the coast of Tunis, where the time was passed in working with various fishing apparatus in shallow water on the south and east coasts of the island. On February 6th, the weather becoming better, we left our anchoring-place at Galita and completed the section. Our route then lay westward, investigations being carried out on the way off the coasts of Tunis and Algeria. From Algiers, where the "Thor" arrived on February 8th, small excursions were made in the neighbourhood, and we departed from this town on February 16th with our course still westwards. Of the work in the westernmost part of the Mediterranean I may specially mention a section from the coast of Africa near Oran to Cape Gata in Spain and a thorough investigation in the Straits of Gibraltar. From the 22nd to the 27th of February we were

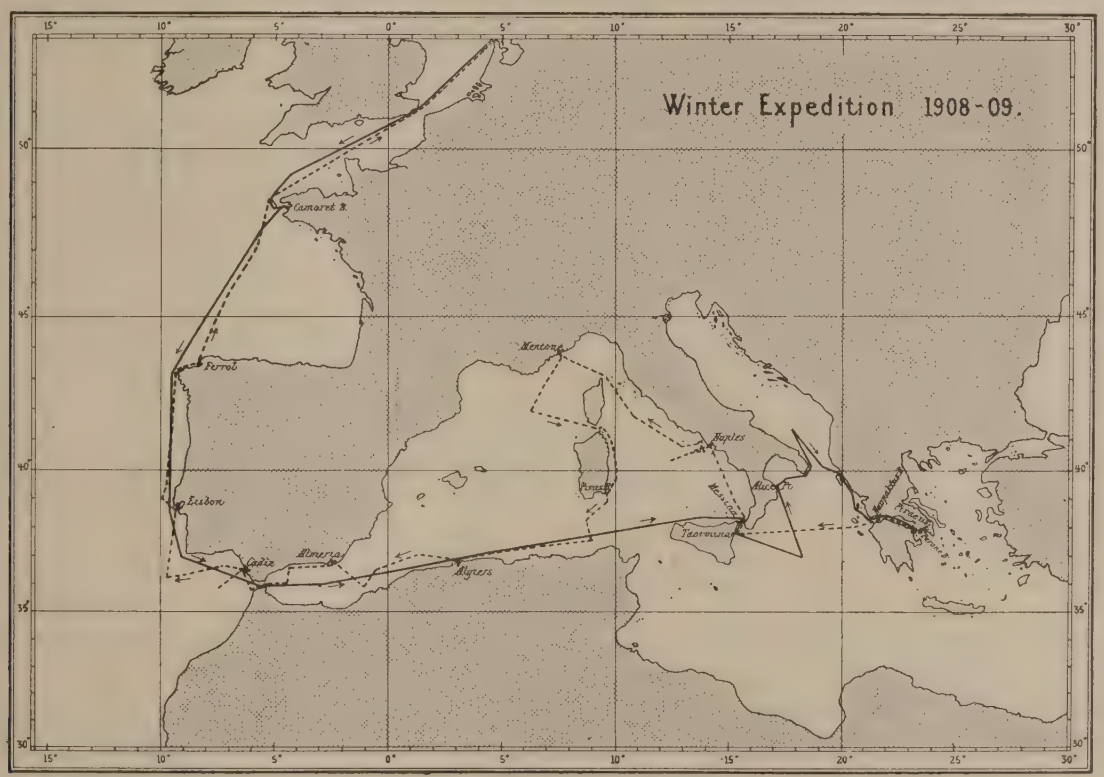

Fig. 11. Winter Cruise 1908—1909.
Route of the "Thor" and calling ports or anchoring places. (The route outwards is indicated by a continuous line, the return voyage by a broken line).

stationed at Cadiz and from there made excursions to various places in the Bay. Thereafter we worked our way along the west coast of the Iberian Peninsula, into the Bay of Biscay and then into the English Channel, carrying out investigations at various places on the way. On March 13th we touched at Dover and on the 18th of the same month arrived at Copenhagen, after some delay in the Belts owing to ice. The distance sailed during this cruise amounted to 8337 miles.

On the winter cruise 78 stations in all were investigated, and at many of these both biological and hydrographical work was done. By far the most of the stations lie in the western basin of the Mediterranean and the waters in the neighbourhood of Gibraltar, whilst relatively few were taken in the eastern basin. The following Table shows the number of stations, the number of horizontal hauls with large pelagic apparatus of stramin (young-fish trawl and ring-trawl), the number made with smaller pelagic appa-

ratus of silk, as also the number of water-samples analyzed for the amount of chlorine, their temperature being noted at the same time, all divided into groups according to the region. Samples from the surface-water taken between the stations are not included.

No. of	Atlantic	Western Mediterranean	Eastern Mediterranean
Stations	24	40	13
Horizontal hauls with apparatus of stramin.	57	90	29
Horizontal hauls with apparatus of silk	7	55	16
Water-samples analyzed	139	408	41

In addition to the investigations enumerated above, some hauls were made with the dredge both from the "Thor" and from our motor-boat, mostly however in shallow water at the anchoring-places, where also collections of the algal vegetation on the coasts were made with the hand-dredges and in other ways. At a few anchoring-places the eel hand-seine was used from the motor-boat for the capture of littoral fishes. When the opportunity presented itself, Dr. Paulsen made collections of the land-vegetation.

On returning home the water-samples were investigated at the Hydrographical Laboratory in Copenhagen. The chlorine contents were determined in all cases and also, for a smaller number of samples from depths of 600 m. and more, the amount of oxygen according to Winkler's method. The samples last-mentioned were collected at the request of Mr. J. P. Jacobsen, who in his paper in the present Volume discusses the results obtained from their examination and from the examination of the samples analyzed on the summer cruise by Mr. S. Palitzsch.

During the greater part of the cruise we were greatly troubled by bad weather, which often hindered or even interrupted our work and forced us to seek shelter wherever we could find it. In this respect we were much disappointed in the winter-season of the Mediterranean, but we must except the last portion, when the conditions were quite favourable at most of our stations off the coast of Africa and round about Gibraltar.

Summer Expedition of 1910.

The summer Expedition of 1910 was made in direct continuation of a cruise with the "Thor" to the Færoes, where we were carrying out fishery investigations in the month of May. The Mediterranean cruise began from Falmouth, to which the "Thor" had come on June 10th from the Færoes. The hydrographer Mr. J. N. Nielsen and the planktologist Dr. Ostenfeld joined us at this port. The "Thor" left Falmouth on the 12th of June, passed Gibraltar on June 23rd on the way out and again on September 7th on leaving the Mediterranean. Our stay in the Mediterranean itself thus lasted two and a half months or exactly the same period as during the winter cruise.

On the voyage from Falmouth to Cadiz, where a couple of days were spent, investigations were made at several stations, and just as on the winter cruise the waters on each side of Gibraltar were subjected to a very careful investigation. In the Alboran Sea, for example, we worked over the same section from Cape Gata across to Oran as in February 1909, and we then followed the coast of Africa to Algiers, where we took in coal on June 27th and proceeded further the same day. With an almost continuous spell of excellent weather we were able in the following days to make a line of investigations across the whole of the Balearic Sea from the coast of Africa to the Ligurian Sea, which we had not succeeded in doing on the winter cruise owing to the storms. On the 3rd of July we arrived at Genoa and lay in the harbour there for the cleaning of the boilers until the 9th, when we sailed southwards and worked in the Tyrrhenian Sea under quite ideal conditions as regards weather. Thereafter we investigated along three important sections, Sardinia — Sicily, Sardinia — Tunis and Tunis — Sicily, for the purpose of ascertaining

and understanding the circulation of the water between the western and eastern basins and between the Balearic and Tyrrhenian Seas.

After two days' rest in the town of Tunis and taking in coal at Malta, the "Thor" left the latter on the 21st of July and devoted the next month to the investigation of the eastern basin of the Mediterranean. As will be seen from the Chart fig. 12, we went from Malta first in the direction S. E. out into the deep Ionian basin and from there southwards right into the head of Syrtis major, where we had our southernmost station for the whole of the cruise close under the Tripolitan coast at 30° 23' N. L. On leaving Sidra we sailed further eastward along the coast of Cyrenaica and Barka with a short stay in the roads of Derna, taking stations all the way. Off the Gulf of Solum we left the African coast to make a

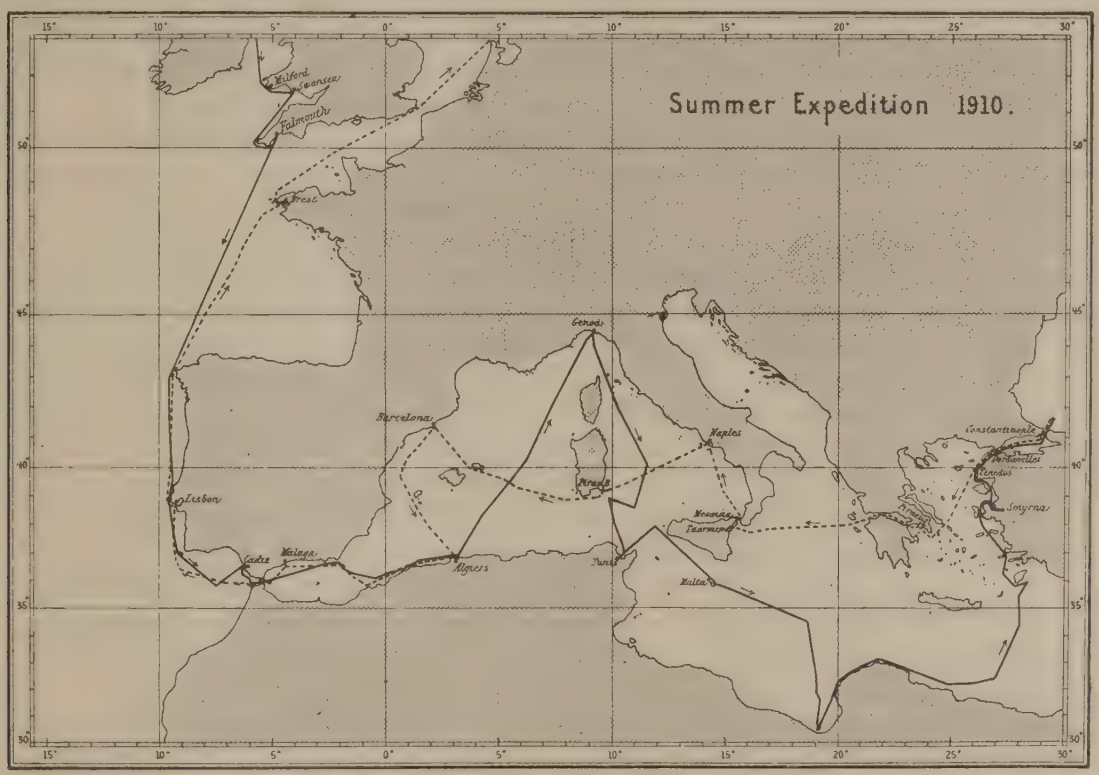

Fig. 12. Summer Cruise 1910.
Route of the "Thor" and calling ports or anchoring places. (The route outwards is indicated by a continuous line, the return voyage by a broken line).

transverse section of the Levant, ending in the deep area S. E. of Rhodes. We then worked in the Aegean Sea and arrived at Smyrna on the 3rd of August after 13 days' uninterrupted work. On the 4th of August, after obtaining permission by telegraph to pass through the Dardanelles, we continued northwards from Smyrna, made a short stay at the island of Tenedos and went into the Sea of Marmora.

In the following week we worked here and in the Bosphorus and Black Sea with a break at Constantinople. On the 12th we passed out through the Dardanelles and again spent some days in the investigation of the Aegean Sea on the way across to Piraeus. On the 16th of August we left the Aegean Sea viâ the Corinth Canal; a short time was spent in the Gulf of Corinth and then we made a section across the Ionian Sea to Taormina. Here we had a coastal station as on the winter cruise and then worked in the Straits of Messina; on the 21st we passed into the Tyrrhenian Sea. We first made some investigations in the south-eastern part on the way to Naples, where we lay for a couple of days to have the

boilers cleaned, and then took a section right across the Tyrrhenian Sea to the south-eastern part of Sardinia. Here we lay for some hours on the 26th of August at the same anchoring-place in Piras Bay as we had visited on the winter cruise and did some dredging etc. in shallow water from the motor-boat. Thereafter we proceeded to make a line of investigations across the Balearic Sea from southern Sardinia to Barcelona, where we arrived on August 30th. On this line we crossed our earlier section over the Balearic Sea from Algiers to Genoa and our station 206 lay very near to the station 116 of June; this was of importance for the discussion of the changes which had occurred in the interval. On the way to Barcelona we passed between Minorca and Majorca and made dredgings here at a station in shallow water. After leaving Barcelona we had a series of stations in the Catalonian Sea, where we also made use of the Monaco trawl on the shallow bank in Valencia Bay. On the 2nd of September we arrived at Algiers, leaving again on the following day westward bound. We now investigated several stations off the coast of Algiers and repeated the section from Oran to Cape Gata across the Alboran Sea, so that this same section was investigated at three different times of the year. On the 7th of September we took in coal at Gibraltar and left the Mediterranean the same day to make investigations in Cadiz Bay and on the coast of Portugal.

After a short stay in Lisbon the investigations were continued northwards along the coast of Portugal and in the Bay of Biscay, ending at Brest. On the 22nd of September we passed by Dover and on the 25th the "Thor" was again in Copenhagen after a voyage of 5 months, during which time 11,165 miles in all had been sailed over (from Falmouth, where the Mediterranean cruise was considered to begin, 9,019 miles). The total number of stations on the Mediterranean cruise amounted to 172, and at a large number of these both biological and hydrographical investigations were made. The distribution of the stations, hauls with stramin and silk apparatus, and the number of water-samples analyzed can be seen from the accompanying Table. It may be remarked, that the relatively few stations in the Sea of Marmora and Black Sea are included under the Eastern Mediterranean. Only the horizontal and pelagic hauls are noted and the surface-samples taken between the stations are not included under the water-samples.

No. of	Atlantic	Western Mediterranean	Eastern Mediterranean
Stations	40	79	53
Horizontal hauls with stramin apparatus	58	130	74
Horizontal hauls with silk apparatus	60	118	79
Water-samples analyzed	179	627	325

In addition to the above we also made a considerable number of hauls with the dredge at all depths and a few hauls with the Monaco trawl, and lines with hooks were set out a few times. Further, the dredges and hand-dredges were used from the motor-boat at the anchoring-places and samples of the coastal fauna and algal flora thus collected. Lastly, when the opportunity presented itself, Dr. Ostenfeld made botanical excursions and collections of the land-vegetation.

On the summer cruise the water-samples were investigated onboard during the voyage, the chlorine titrations were made by Mr. Nielsen, the oxygen titrations by Mr. S. Palitzsch, and only a very few samples from great depths were kept till the return home, as Mr. Nielsen desired to have their chlorine contents determined with the greatest possible amount of accuracy. The result of the analysis of these samples will be found in the report by Mr. H. Bjørn-Andersen in this Volume.

In great contrast to the winter cruise our second cruise in the Mediterranean was favoured by the best possible weather. On none of our earlier cruises had we experienced such favourable conditions as on this, when a perfectly smooth surface or light breeze was the rule, wind-force of 6—7 a rarity, and we were not once hindered in our work by the weather, as was continually the

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case on the winter cruise. It is not to be wondered at, therefore, that we succeeded in carrying out our plans in all essentials and even found time to penetrate into the Sea of Marmora and Black Sea. This was of the greatest interest to us, as we were able to see in the most striking manner the importance of the low salinity for the composition and character of the fauna and flora.

Finally, I may give here for both of the cruises a list of the ports called at and the anchoring-place, with the dates.

Winter Cruise 1908—1909.

November	13th	left	Copenhagen.
..	15th	arrived	Kiel.
„	28th	„	Camaret Bay (Brittany).
December	5th	passed	Gibraltar.
..	7th	arrived	Algiers.
„	12th	„	Messina.
..	13th	„	Taormina Roads.
..	17th	„	Alice Point (Calabria).
..	23rd	„	Navpaktos Bay (Greece).
..	25th	„	Piraeus.
..	31st	„	Perane Bay (Greece).
„	31st	„	Piraeus.
January	5th	„	Messina Straits.
„	8th	„	Naples.
„	23rd	„	Mentone.
February	2nd	„	Piras Bay (Sardinia).
..	3rd	„	Galita Island (Tunis).
..	8th	„	Algiers.
..	19th	„	Almeria Roads.
„	21st	passed	Gibraltar.
„	22nd	arrived	Cadiz Roads.
March	2nd	„	Lisbon.
..	6th	„	Ferrol Roads.
..	13th	passed	Dover.
„	16th	arrived	Korsør.
..	18th	„	Copenhagen.

Summer Cruise 1910.

April	28th	left	Copenhagen.
„	29th	arrived	Frederikshavn.
May	5th	„	Aberdeen.
„	12th	„	Færoe Islands.
June	1st	left	„ „
„	3rd	arrived	Stornoway.
„	6th	„	Milford Roads.
„	6th	„	Swansea.
„	10th	„	Falmouth Roads.
„	12th	left	„ „
„	19th	arrived	Cadiz Roads.
„	23rd	passed	Gibraltar.
„	27th	arrived	Algiers.
July	3rd	„	Genoa.
„	16th	„	Tunis.
„	21st	„	Malta.
August	3rd	„	Smyrna.
„	5th	„	Tenedos.
„	5th	passed	Dardanelles.
„	6th	arrived	Constantinople.
„	12th	passed	Dardanelles.
„	14th	arrived	Piraeus.
„	19th	„	Taormina Roads.
„	22nd	„	Naples.
„	26th	„	Piras Bay (Sardinia).
„	30th	„	Barcelona.
September	2nd	„	Algiers.
„	6th	„	Malaga Roads.
„	7th	„	Gibraltar.
..	11th	..	Lisbon.
..	18th	„	Brest.
..	22nd	passed	Dover.
..	25th	arrived	Copenhagen.

IV. Material collected by the Expeditions and supplementary information acquired later.

Importance of the material.

Regarding the importance of the hydrographical material it is superfluous to say anything at this place; I need only refer to the reports in this Volume by J. N. Nielsen, J. P. Jacobsen and S. Palitzsch. On the other hand, it may be opportune to mention the uses and importance of the biological material.

The biological collections have been made with the steadfast purpose in mind of obtaining information regarding the commonest and most important organisms; in discovering "rare" or "new" species we have taken no special interest. So far as possible, hydrographical investigations were always made in conjunction with the biological collections. We are thus in a position to determine precisely, under what conditions the organisms found have lived, a matter to which I ascribe the very greatest importance and which has been one of the leading ideas of the Expeditions. For this reason, also, we first publish here the results of the hydrographical investigations, so that their details may be accessible to the biologists who are engaged in the study of our biological material.

The first and chief importance must be ascribed to the pelagic collections, which have been obtained through systematic work over wide regions, with apparatus which we know to fish excellently well. If we exclude the larger animals which are rapid swimmers, such as the large fishes, cuttle-fish and the like, we may consider that the apparatus used fishes so well, that the hauls give a fairly correct picture of what really lives at the place and depth investigated. We are thus able to draw conclusions not only from positive hauls, that is, indicating the occurrence of this or that organism, but also from negative hauls which indicate their absence or scarcity.

Among the pelagic organisms, it is especially those occurring over and at great depths which are best represented in our collections. Our work in the coastal waters has not been sufficiently regular or extensive to permit us to think, that we have taken everything that is essential. Furthermore, there are several biological stations on the coasts of the Mediterranean, which are engaged in the study of the organisms living at the coasts, and the desire not to trespass on the work so excellently carried out from them has also contributed to my resolution to restrict our work essentially to the more open sea.

Our first endeavour is to characterize the pelagic fauna of the Mediterranean by the side of that of the Atlantic, from a comparison of the species and an investigation of how far the species common to both regions penetrate into the Mediterranean. The great difference between the Atlantic and Mediterranean in hydrographical regards is the best reason and opportunity for seeking to elucidate, what are the hydrographical factors which determine the distribution of the species.

But it is not only the horizontal distribution of the species we take into consideration, the vertical has just as much interest, and our hauls in different depths at the same station often yield good information on this point. We are indeed entitled, in seeking to form a picture of the bathymetric occurrence of a species, to proceed in the following manner, using naturally all possible caution. All the stations are picked out where the species is taken. The total number of specimens found at the same depth is then ascertained and also the total number of hours the apparatus has fished at the depth in question. The number of specimens divided by the number of hours gives then a value, which corresponds to the quantitative occurrence of the species at that depth. The same is done for all the depths in which fishing has been carried on and we thus find, in what layer of water the species mainly or only occurs. We must, naturally, take into account here the irregularities due to the fact, that an open apparatus, e. g. the young-fish trawl, also fishes when being hauled in, and such comparisons should therefore only be made with

species, which occur in fairly large numbers at the different stations. Similarly we must also remember that certain species undertake vertical wanderings in the course of the 24 hours.

In our biological investigations we endeavour to advance a step further in the direction of geographical zoology and botany, which regards the species or races as units. For the biologist the species must be split up into their different developmental stages, and we must endeavour to elucidate the occurrence of the latter and the biological conditions under which they live, just as if we were dealing with different species. We must investigate, therefore, under what hydrographical conditions the various developmental stages of a species occur and we must study both the horizontal and vertical distribution of these. With few exceptions it has hitherto been only the fishes whose life-history has been studied in this way, and it has been found, that a species during its development from egg to adult, spawning animal often displays great differences both in horizontal and vertical distribution and that the different developmental stages are often bound to definite times of the year. To make this clear, I need only recall, that many of the fishes living on the bottom, even deep-water fishes, have larval stages which live in the upper layers, that most fishes have a definite spawning-period and that the spawning-region of a fish is often quite different from and much more restricted than its region of occurrence as a whole [1]. It will seem quite natural that this mode of study should first and foremost be directed towards the fishes, but a similar investigation may be carried out for all the species of lower animals which live pelagically. In this direction there is much to learn and here our material can be of great use. What do we know, for example, regarding the spawing times of the lower animals, regarding the depths and places where they spawn and regarding their mode and rate of growth and age? To deal with the material in this manner, it will be necessary in many cases to carry out some preliminary work, for the purpose of distinguishing between and describing the different developmental stages of the various species, just as we have been obliged to do in the case of the fishes, especially the northern, the life-history of which has been to some extent elucidated.

Supplementary information acquired later.

During the examination of the material, both hydrographical and biological, there sometimes arose the desire to have supplementary information on one point or other. Even though the two cruises had visited the greater part of the Mediterranean and covered both the winter and summer periods, yet there were both places and periods from which material was wanting. Through the friendly assistance of many different institutions and persons we have succeeded in obtaining additional material in several cases.

With regard to the hydrographical investigations, it was especially the question of the winter cooling of the surface-water in the central and northern part of the Balearic Sea and elsewhere, and of the concentration of the surface-water in summer etc., concerning which we desired further information. It should be mentioned, first of all, that Dr. J. Richard, Director of the Oceanographical Institute in Monaco, obtained for us 8 series of hydrographical observations at different depths in the neighbourhood of Monaco. The observations were carried out in September and October 1909 and in the spring and summer of 1910, and samples were sent us for the analysis of the chlorine and oxygen contens. Further, from a no small number of Danish and foreign merchant-ships temperature observations and water-samples from the surface have been taken in the most different parts of the Mediterranean at all times of the year. The temperature observations were as a rule made by the first mate, and the water-samples have all been analyzed for chlorine at the Hydrographical Laboratory in Copenhagen which is under the direction of Docent Martin Knudsen. The steamship companies from whose vessels the hydrographical observations have been made, are the East-Asiatic Company, Copenhagen, United Steamship Company, Copenhagen, Compagnie

[1] Illustrations of this will be found in my papers cited on p. 4.

Générale Transatlantique, Paris, Norddeutscher Lloyd, Bremen and Oesterreichischer Lloyd, Triest. Lastly, Capt. G. HANSEN of the "Thor" during a stay at Messina in the spring of 1911, made a number of vertical series of temperature observations in the Straits of Messina. A list of all these hydrographical observations will be found on p. 71 et seq.

Supplementary biological collections have also been made for us in the Mediterranean and adjacent parts of the Atlantic. They consist of horizontal hauls with nets of stramin, varying in size from 1 to 2 m. A list of these hauls is given on p. 47 in continuation of the list of the stations of the "Thor". The hauls have been made from vessels of the Royal Danish Navy, East-Asiatic Company and United Steamship Company of Copenhagen. As the same apparatus have been used as on the "Thor", the hauls are in general comparable with ours. The collections of these vessels were mainly made at the times of the year, when the "Thor" was not at work, which naturally increases their importance. The same applies to a series of collections made by Capt. G. HANSEN of the "Thor" in the Straits of Messina in the spring of 1911 with a stramin net, 1 m. in diameter.

As a very important supplement to the material obtained in the Atlantic in 1908—1910 may finally be mentioned the material, which was collected on our cruises with the "Thor" in the waters west and south of the British Isles in the years 1905 and 1906. This material, which was collected in quite the same way as that of our Mediterranean cruises, is still only partially worked up and published, and may be used with great advantage in connection with the present material. The stations from these earlier years are indicated in the lists by the numbers 05 and 06.

V. List of the Stations.

1. **Stations taken during the "Thor" Expeditions to the Mediterranean.**
   a. Winter Expedition 1908—1909.
   b. Summer Expedition 1910.
2. **Stations of the "Thor" in the Atlantic S. of Ireland 1905 and 1906.**
3. **Supplementary stations of various other vessels.**
   a. in the Mediterranean.
   b. in the Atlantic.

Abbreviations.

O ..... Otter-trawl, head-rope 15.25 m. (50 feet).
Y 200... Young-fish trawl, 200 cm. in diam. at opening.
Y 330... — — — 330 — - — - —
C 200... Ring-trawl, 200 cm. in diam. at opening.
C 130... — — 130 — - — - —
S 100... Stramin-net, open, conical, 100 cm. in diam. at opening.
S 150... — — — — 150 — - — - —
S 200... — — — — 200 — - — - —
P 100... Silk-net, open, conical, 100 cm. in diam. at opening, gauze No. 3.
P 30.... — — — — 30 — - — - — — — 20.
N 50 ... Nansen's closing net, 50 cm. in diam. at opening, gauze No. 20.
N 30 ... — — — 30 — - — - — — — —
A 16.... Apstein's medium-sized closing net, 16 cm. in diam. at opening, gauze No. 20.
T 25.... Taffeta-net, open, conical, 25 cm. in diam.
G 68.... Hensen-net, 68 cm. in diam. at opening, gauze No. 3.
D 1 .... Dredge, rectangular opening, 27 × 117 cm.
D 2 .... — triangular opening, 45 × 45 cm.
H ..... Hand-Dredge, 18 × 14 cm.
Aa 1 ... Eel hand-seine.
Aa 2 ... — drift-seine.
Aa T ... — -trawl.
R ..... Shrimp-net.
R. T.... — -trawl.
M ..... Monaco-trawl, 56 × 170 cm. at opening.
L ..... Long-lines.
W ..... White disc, 15 cm. in diam., used for determining the relative transparency of the water.
Hy .... Hydrographical observations, e. g. "Hy 1000—0" = observations from a depth of 1000 m. up to the surface

blk.	black.	rd.	red.
c.	coarse.	s.	sand.
cl.	clay.	sft.	soft.
crl.	coral.	sh.	shells.
f.	fine.	st.	stones.
g.	gravel.	stf.	stiff.
m.	mud.	wd.	weed.
oz.	ooze.	y.	yellow.
r.	rock.		

I. Stations taken during the "Thor" Expeditions to the Mediterranean.

a. Winter Expedition.

Station Nr.	Date	Hour	Position Lat. N.	Position Long.	Depth Meters	Nature of bottom	Weather	Wind Direction 0—12	Wind Force 0—12	Sea Direction 0—12	Sea Force 0—12	Temperature Air	Temperature Surface	Surface Cl ‰	Surface S ‰	Gear	Wire out Meters	Duration of haul in minutes
								Channel and Atlantic.										
				W														
1	28/11 08	2[50] a. m.	49°17′	4°13′	94	"	Cloudy	SSW	5	SW	6	10°5	12°4	"	"	Y 200	25	30
2	"	10[30] a. m.	48°44′	4°55′	112	"	"	SSW	7	W	7	12°0	13°5	"	"	Y 200	65	30
3	30/11 08	1[15] p. m.	47°45′	5°28′	130	"	"	SSE	6	W	5	12°0	13°4	"	"	Y 200	65	30
4	1/12 08	11[45] a. m.	45°20′	7°42′	> 4000	"	"	SE	2	W	4	17°5	15°6	"	"	C 130	1500	30
"	"	1[05] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	65	30
"	"	2[00] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Hy	1000—0	"
5	2/12 08	9[15] a. m.	43°10′	9°30′	180	"	Cloudy	SSW	2	W	4	15°2	15°6	"	"	Y 200	65	30
6	3/12 08	9[00] p. m.	38°44′	9°38′	188	"	"	SSE	3	W	5	16°0	16°4	"	"	Y 200	65	30
7	4/12 08	10[45] a. m.	37°00′	9°07′	85	"	Clear	ESE	3	W	5	18°0	18°0	"	"	Y 200	65	15
8	4/12 08	8[20] p. m.	36°33′	7°36′	> 600	"	"	E	3	W	4	17°5	17°8	"	"	Y 200	65	30
								Mediterranean (Eastern Basin).										
				E														
9	14/12 08	10[00] a. m.	Taormina Bay 37°50′	15°18′	21	st.	Cloudy	SSW	2	SE	3	15°9	15°9	"	"	D 1	30	30
"	"	10[30] a. m.	"	"	7	"	"	"	"	"	"	"	"	"	"	D 1	15	30
"	"	11[00] a. m.	"	"	13	"	"	"	"	"	"	"	"	"	"	D 1	22	30
"	"	11[30] a. m.	"	"	6—30	"	"	"	"	"	"	"	"	"	"	D 1	11—47	30
"	"	11[45] a. m.	"	"	0—1/2	r.	"	"	"	"	"	"	"	"	"	H	"	"
"	"	8[30] p. m.	"	"	23	st.	"	NW	2	"	"	"	"	"	"	D 1	188	5
																P 30	Surf.	"
10	15/12 08	5[00] a. m.	37°21′	16°45′	> 2100	"	Cloudy	SSW	2	ENE	2	"	"	"	"	Y 200	25	60
"	"	6[10] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	65	60
"	"	8[00] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	C 130	300	30
"	"	9[30] a. m.	"	"	"	"	"	SW	3	"	"	14°5	16°5	"	"	Y 200	1200	60
																Y 200	600	60
"	"	3[45] p. m.	"	"	"	"	"	SW	4	SW	3	"	"	"	"	P 30	Surf.	5
11	16/12 08	4[00] a. m.	36°57′	18°16′	> 3700	"	Cloudy	SW	4	SW	4	"	"	"	"	Y 200	25	60
"	"	5[25] a. m.	"	"	"	"	"	SSW	5	SW	5	"	"	"	"	Y 200	65	60
"	"	7[00] a. m.	"	"	"	"	"	S	5	S	5	"	"	"	"	Y 200	300	120
"	"	9[30] a. m.	"	"	"	"	"	S by E	5	S by E	5	"	"	"	"	Y 200	1000	180
																Hy	1500—0	"
"	"	2[00] p. m.	"	"	"	"	"	SW	4	SW	4	16°5	16°6	21.07	38.06	P 30	Surf.	5
12	19/12 08	11[40] a. m.	39°34′	17°17′	1060	cl.	Squally	Baffling	"	SE	4	"	"	"	"	Y 200	300	60
																Y 200	65	30
"	"	1[00] p. m.	"	"	"	"	"	SE	3	"	"	"	"	"	"	P 30	Surf.	5
"	"	2[15] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	1000	45
"	"	2[20] p. m.	"	"	"	"	Rain	SSE	4	"	"	13°0	14°2	"	"	P 100	Surf.	5
																Y 200	300	60
13	19/12 08	5[35] p. m.	39°43′	17°30′	> 1200	"	Cloudy	SSE	3	SE	4	"	"	"	"	P 30	Surf.	5
"	"	7[05] p. m.	"	"	"	"	"	E	3	"	"	"	"	"	"	Y 200	1000	60
"	"	8[50] p. m.	"	"	"	"	Rain	S	4	SSE	4	"	"	"	"	Y 200	65	60
"	"	10[15] p. m.	"	"	"	"	"	"	"	"	"	13°2	14°4	"	"	Y 200	15	60
																Y 200	65	60
14	21/12 08	5[00] a. m.	41°24′	17°45′	1125	cl.	Cloudy	NE	6	NE	5	"	"	"	"	P 30	Surf.	5
"	"	5[20] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	6[30] a. m.	"	"	"	"	"	ENE	6	ENE	5	13°9	13°7	"	"	Y 200	300	60
"	"	8[20] a. m.	"	"	"	"	"	"	7	"	7	"	"	"	"	Y 200	1000	90
15	22/12 08	1[30] a. m.	40°04′	19°06′	"	"	Cloudy	SE	4	SE	4	"	"	"	"	Y 200	65	60
"	"	2[40] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	60
"	"	5[20] a. m.	"	"	1000	cl.	"	"	"	"	"	"	"	"	"	Y 200	1400	60
"	"	8[00] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	1400	60
																Hy	950—0	"
"	"	11[00] a. m.	"	"	"	"	"	"	"	"	"	15°5	15°2	"	"	P 30	Surf.	5
16	22/12 08	8[35] p. m.	39°34′	20°01′	70	"	Cloudy	ESE	4	ESE	2	13°8	15°0	"	"	Y 200	65	30
																P 100	Surf.	5
"	"	8[40] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 30	Surf.	5
17	30/12 08	1[10] p. m.	37°49′	23°27	55	s. sh.	Cloudy	SE	4	SE	2	16°0	15°5	"	"	D 1	115	10
																D 1	50	5
"	"	2[30] p. m.	"	"	19	"	"	"	"	"	"	"	"	"	"	P 30	Surf.	5
18	30/12 08	4[10] p. m.	37°51′	23°14′	220	cl.	Rain	NW	4	NW	3	"	"	"	"	D 1	380	10
"	"	4[40] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	D 1	300	10
"	"	5[10] p. m.	"	"	"	"	Squally	"	"	"	"	"	"	"	"	D 1	350	30

Station Nr.	Date	Hour	Position Lat. N.	Position Long. E.	Depth Meters	Nature of bottom	Weather	Wind Direction 0—12	Wind Force 0—12	Sea Direction 0—12	Sea Force 0—12	Temperature Air	Temperature Surface	Surface Cl ‰	Surface S ‰	Gear	Wire out Meters	Duration of haul in minutes
18	30/12 08	7[00] p. m.	37°51′	23°14′	220	cl.	Squally	NW	4	NW	3	16°0	15°5	"	"	Y 200	25	60
"	"	8[30] p. m.	"	"	"	"	Rain	"	"	"	"	14°5	15°2	21.26	38.40	Hy	200—0	"
"	"	9[30] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	60
"	"	9[35] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
																P 30	Surf.	5
19	31/12 08	8[00] a. m.	Perane Bay 37°54′	23°20′	11	st.	Cloudy	Calm	"	SSE	1	"	"	"	"	D 1	17	30
"	"	9[00] a. m.	"	"	1	"	"	"	"	"	"	"	"	"	"	H	"	"
"	"	9[30] a. m.	"	"	6—7	s.	"	SE	4	SE	1	"	"	"	"	D 1	15	30
"	"	10[00] a. m.	"	"	6—7	st.	"	"	"	"	"	"	"	"	"	D 1	11	30
"	"	10[30] a. m.	"	"	1	"	"	"	"	"	"	"	"	"	"	H	"	"
"	"	11[30] a. m.	"	"	19	cl.	"	"	"	"	"	"	"	"	"	D 1	60	"
20	5/1 09	3[10] a. m.	37°48′	15°49′	>1300	"	Cloudy	NNE	4	ENE	4	11°0	15°1	"	"	Y 200	25	60
"	"	3[30] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
																P 30	Surf.	5
21	5/1 09	11[50] p. m.	37°51′	15°21′	> 500	"	Clear	NNW	1	NE	2	11°6	15°4	"	"	Y 200	10	30

Mediterranean (Western Basin).

22	7/1 09	8[00] p. m.	38°50′	15°18′	> 750	"	Cloudy	Calm	"	0	"	12°8	14°7	"	"	Y 200	25	30
																Y 200	200	30
"	"	8[45] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 30	Surf.	5
23	15/1 09	11[50] p. m.	40°34′	13°24′	>1800	"	Cloudy	W	2	W	Swell	16°8	14°0	"	"	Y 200	25	30
"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
																P 30	Surf.	5
24	16/1 09	7[50] a. m.	40°14′	12°23′	>3700	"	Cloudy	NW	2	WSW	Swell	"	"	"	"	Y 200	65	30
"	"	9[00] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	60
"	"	11[30] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	C 130	3000	60
"	"	2[10] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	600	60
"	"	5[20] p. m.	"	"	"	"	"	"	"	"	"	13°3	14°15	21.00	37.94	Hy	2130—0	"
"	"	9[10] p. m.	"	"	"	"	"	NNW	1	WSW	4	"	"	"	"	Y 200	300	30
"	"	10[00] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	30
"	"	11[15] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	1600	240
"	17/1 09	4[30] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	65	120
																Y 200	300	120
"	"	7[15] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 30	Surf.	5
25	17/1 09	4[40] p. m.	40°34′	13°24′	>1800	"	Clear	NNW	6	NW	5	14°3	14°0	"	"	Y 200	65	30
																P 30	Surf.	5
"	"	4[50] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	5[40] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	60
26	18/1 09	0[45] a. m.	40°40′	13°59′	560	"	Clear	NE	5	NE	2	"	"	"	"	Y 200	65	60
"	"	2[15] a. m.	"	"	"	"	"	"	"	"	"	9°4	14°3	"	"	Y 200	300	60
"	19/1 09	0[50] a. m.	"	"	"	"	"	N	3	N	3	"	"	"	"	Y 200	150	180
"	"	4[20] a. m.	"	"	"	"	"	"	2	"	2	9°8	14°3	"	"	Y 200	25	120
																Y 200	300	180
"	"	6[40] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 30	Surf.	5
27	19/1 09	0[45] p. m.	40°58′	13°49′	90	cl.	Cloudy	E	2	E	2	8°6	13°3	"	"	Y 200	200	30
																Y 200	130	30
"	"	3[00] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 30	Surf.	5
"	"	3[10] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	20/1 09	2[30] a. m.	"	"	"	"	"	NE	3	NE	2	"	"	"	"	Y 200	25	180
"	"	6[00] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	65	120
28	19/1 09	5[00] p. m.	40°53′	13°43′	600	m.	Cloudy	E	3	E	2	8°4	13°2	"	"	Y 200	1000	60
"	"	6[40] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	400	30
"	"	7[30] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	60
"	"	9[00] p. m.	"	"	"	"	"	"	4	"	4	"	"	"	"	Y 200	200	30
"	"	10[00] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	100	60
																Y 200	65	120
"	"	11[50] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 30	Surf.	5
29	20/1 09	2[15] p. m.	40°47′	12°55′	1550	cl.	Cloudy	NW	1	NW	2	"	"	"	"	Y 200	1650	60
																P 30	Surf.	5
"	"	4[00] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	7[20] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	200	60
"	"	8[40] p. m.	"	"	"	"	"	Calm	"	"	"	9°6	14°2	"	"	Y 200	65	30
"	"	9[30] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	600	60
30	21/1 09	5[30] a. m.	41°15′	11°55′	>1800	"	Cloudy	NW	3	NW	4	"	"	"	"	Y 200	65	60
"	"	7[10] a. m.	"	"	"	"	"	"	"	"	"	9°6	13°6	21.03	37.99	Y 200	300	60
																Hy	1800—0	"
"	"	8[00] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 30	Surf.	5
31	21/1 09	10[00] p. m.	41°44′	10°52′	1420	cl.	Cloudy	NE	4	NNE	4	8°6	13°0	21,06	38.04	Hy	1400—0	"

Station Nr.	Date	Hour	Position Lat. N.	Position Long. E.	Depth Meters	Nature of bottom	Weather	Wind Direction 0—12	Wind Force 0—12	Sea Direction 0—12	Sea Force 0—12	Temperature Air	Temperature Surface	Surface Cl ‰	Surface S ‰	Gear	Wire out Meters	Duration of haul in minutes
31	22/1 09	1h a. m.	41°44′	10°52′	1420	cl.	Cloudy	NE	4	NNE	4	8°6	13°0	21.06	38.04	Y 200	1400	60
"	"	3m a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	600	30
"	"	3h15 a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 30	Surf.	5
"	"	3h50 a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	4h30 a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	200	30
"	"		"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	65	30
32	22/1 09	2h00 p. m.	42°45′	9°50′	640	cl.	Clear	NE	3	NE	3	12°5	13°7	20.99	37.92	Hy	600—0	"
"	"	3h00 p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
33	22/1 09	4h00 p. m.	43°04′	9°35′	150	cl.	Cloudy	E	3	E	4	9°1	13°0	21.08	38.08	T 25	Surf.	"
"	"	6h30 p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Hy	140—0	"
"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	65	30
34	23/1 09	4h35 a. m.	43°27′	8°16′	>2000	"	Cloudy	NE	5	NE	5	9°0	13°0	"	"	P 100	Surf.	5
"	"	5h30 a. m.	"	"	"	"	"	"	6	"	6	"	"	"	"	P 30	Surf.	5
"	"	6h35 a. m.	"	"	"	"	"	"	7	"	7	"	"	"	"	Y 200	25	30
"	"	7h00 a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	65	30
"	"		"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	200	30
35	28/1 09	6h00 p. m.	43°36′	7°36′	>2000	"	Rain	ENE	6	E	6	11°5	12°8	21.06	38.04	P 100	Surf.	5
"	"	9h40 p. m.	"	"	"	"	Clear	WSW	4	SW	2	"	"	"	"	Hy	2000—0	"
"	29/1 09	11h35 a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	120
"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	1600	120
"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	S 100	1000	120
"	"	11h30 a. m.	"	"	"	"	"	SW	3	"	"	"	"	"	"	S 100	700	120
"	"	3h45 a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 30	Surf.	5
"	"	6h40 a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	7h55 a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	C 200	2500	90
"	"	9h10 a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	200	60
36	30/1 09	5h35 a. m.	42°49′	6°54′	>2000	"	Clear	WSW	4	WSW	4	10°6	12°1	"	"	Y 200	100	60
"	"	6h50 a. m.	"	"	"	"	"	"	5	"	5	"	"	"	"	Y 200	25	60
37	30/1 09	5h00 p. m.	41°56′	6°18′	>2600	"	Misty	W by N	7	NW	7	10°5	12°1	21.17	38.24	Y 200	65	60
38	31/1 09	6h30 p. m.	40°45′	9°50′	105	"	Cloudy	W by N	7	W	4	"	"	"	"	Hy	2000—0	"
"	"	7h10 p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	65	30
"	"	7h20 p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	30
"	"	8h20 p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 30	Surf.	5
"	"	9h00 p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
39	1/2 09	5h00 a. m.	39°41′	10°02′	1750	cl.	Cloudy	NW	4	N	3	"	"	"	"	Y 200	150	30
"	"	6h10 a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Hy	100—0	"
"	"	7h20 a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	60
"	"	7h30 a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	65	60
"	"	9h00 a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	60
"	"	0h30 p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 30	Surf.	5
"	"	9h00 p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
40	1/2 09	8h00 p. m.	39°10′	9°40′	235	m.	Squally	WNW	6	W	3	9°8	13°2	20.99	37.92	Hy	1700—0	"
"	"	9h30 p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	1000	120
"	"	9h40 p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Hy	230—0	"
41	2/2 09	a. m.	Piras Bay, Sardinia		19	s.	Cloudy	NNW	8	NW	2	"	"	"	"	Y 200	65	30
"	"	2h15 p. m.	39°10′	9°35′	4 - 8	st.	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	2h45 p. m.	"	"	8 -11	"	"	"	"	"	"	"	"	"	"	P 30	Surf.	5
"	"	3h00 p. m.	"	"	0—1	"	"	"	"	"	"	"	"	"	"	D 1	8 hauls	"
"	"	4h00 p. m.	"	"	0—1	"	"	"	"	"	"	"	"	"	"	D 1	25	30
"	"	5h00 p. m.	"	"	0—1	"	"	"	"	"	"	"	"	"	"	D 1	25	30
42	2/2 09	7h00 p. m.	38°58′	9°37′	1120	cl.	Clear	NE	4	NE	4	"	"	"	"	H	"	30
"	"	9h40 p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	H	"	30
"	"	9h50 p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	R	"	60
43	3/2 09	6h15 a. m.	38°14′	8°42′	>2000	cl.	Clear	NW	5	NW	5	"	"	"	"	Hy	1000—0	"
"	"	7h00 a. m.	"	"	"	"	"	"	"	"	"	13°2	13°8	20.69	37.38	Y 200	300	30
14	1/2 09	a. m.	South coast of Galita		25	s.	Cloudy	WNW	9	W	3	"	"	"	"	P 30	Surf.	5
"	"	"	37°31′	8°57′	8 - 25	s.	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	p. m.	"	"	0—1	wd.	"	"	"	"	"	"	"	"	"	D 1	8 hauls	"
"	3/2 09	a. m.	East coast of Galita		17	s.	"	NW	8	SW	Swell	"	"	"	"	D 1	7 hauls	"
"	"	p. m.	"	"	9—17	"	"	"	"	"	"	"	"	"	"	H	"	"
"	6/2 09	a. m.	"	"	17	"	"	"	7	"	"	"	"	"	"	D 1	8 hauls	"
45	6/2 09	8h00 p. m.	37°28′	8°18′	>2150	"	Cloudy	NW	4	NW	5	13°4	14°0	20.48	37.00	D 1	12 hauls	"
"	"	11h25 p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Aa	8 hauls	"
"	7/2 09	0h15 a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Hy	2000—0	"
																Y 200	300	30
																Y 200	65	30
																P 30	Surf.	5

Station Nr.	Date	Hour	Position Lat. N.	Position Long.	Depth Meters	Nature of bottom	Weather	Wind Direction 0—12	Wind Force 0—12	Sea Direction 0—12	Sea Force 0—12	Temperature Air	Temperature Surface	Surface Cl ‰	Surface S ‰	Gear	Wire out Meters	Duration of haulin minutes
				E														
45	7/2 09	0[25] a. m.	37°28′	8°18′	>2150	s.	Cloudy	NW	4	NW	5	13°4	14°0	20.48	37.00	P 100	Surf.	5
46	7/2 09	4[00] p. m.	37°17′	6°00′	>1930	"	Cloudy	NW	2	NNE	4	13°5	14°2	20.44	36.92	Hy	1900—0	"
																Y 200	600	30
"	"	6[35] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 30	Surf.	5
"	"	6[45] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	7[30] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	30
"	"	8[20] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	65	30
46 a	8/2 09	6[45] p. m.	37°09′	4°24′	>2000	"	Cloudy	NE	4	NE	6	"	"	"	"	Hy	2000—0	"
47	8/2 09	6[00] p. m.	36°55′	3°12′	>2000	"	Cloudy	W by N	3	WNW	4	14°8	14°5	20.35	36.76	Hy	2000—0	"
"	10/2 09	10[30] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	65	30
"	"	11[05] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	30
48	11/2 09	p. m.	Algiers Harbour		0—1	st.	Rain	NNW	6	0	0	"	"	"	"	H	"	"
																P 30	Surf.	5
49	16/2 09	1[40] p. m.	36°55′	2°16′	>2000	"	Squally	N	2	NE	4	12°9	14°4	"	"	P 100	Surf.	5
50	16/2 09	11[00] p. m.	37°02′	1°17′	>2000	"	Clear	W	3	W	3	12°8	13°4	20.70	37.39	Hy	2000—0	"
"	17/2 09	1[20] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	30
"	"	2[00] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	65	30
"	"	2[40] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	30
"	"	3[35] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	30
																P 30	Surf.	5
"	"	3[40] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	4[10] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	600	30
"	"	5[30] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	1600	60
				W														
51	17/2 09	11[00] p. m.	36°27′	0°37′	>2000	"	Clear	ESE	3	ESE	3	12°5	14°0	20.31	36.69	Hy	2000—0	"
"	18/2 09	0[50] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	30
																P 100	Surf.	5
"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	P 30	Surf.	5
52	18/2 09	7[25] a. m.	35°55′	1°02′	>2000	"	Cloudy	SW	3	SW	3	"	"	"	"	Y 200	300	30
"	"	8[00] a. m.	"	"	"	"	"	"	"	"	"	17°5	14°35	20.30	36.67	Hy	2000—0	"
																P 100	Surf.	5
"	"	10[30] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 30	Surf.	5
53	18/2 09	3[00] p. m.	36°13′	1°28′	>2000	"	Cloudy	NE	3	NE	3	15°5	13°87	20.62	37.25	Hy	1500—0	"
"	"	5[15] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	C 200	2600	90
																P 100	Surf.	5
"	"	5[30] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 30	Surf.	5
54	19/2 09	1[00] a. m.	36°30′	1°54′	1450	cl.	Clear	NE	4	NE	4	13°5	13°5	20.75	37.48	Hy	1400—0	"
55	19/2 09	6[30] a. m.	36°46′	2°18′	75	cl. s.	Misty	NE	6	NE	4	12°5	13°6	"	"	Y 200	25	60
"	"	7[40] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	65	60
																P 100	Surf.	5
"	"	8[00] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 30	Surf.	5
56	19/2 09	p. m.	Almeria Bay		12	cl.	Cloudy	E	1	E	1	14°8	13°5	"	"	D 1	16 hauls	"
57	20/2 09	5[45] a. m.	36°40′	3°30′	105	st.	Cloudy	N	2	E	2	13°2	13°8	"	"	Y 200	25	30
"	"	6[35] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	200	30
																P 100	Surf.	5
"	"	6[45] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 30	Surf.	5
58	20/2 09	1[00] p. m.	36°36′	4°24′	85	m.	Cloudy	SSW	2	S	2	16°5	13°65	20.37	36.80	Hy	75—0	"
"	"	2[00] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	100	30
																P 30	Surf.	5
"	"	2[10] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	3[00] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	65	30
59	20/2 09	10[00] p. m.	36°02′	4°24′	1260	m.	Clear	SE	5	SE	5	14°0	14°5	20.17	36.44	Hy	1240—0	"
																Y 200	25	30
"	21/2 09	0[10] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 30	Surf.	5
"	"	1[15] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	1[00] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	100	30
"	"	1[40] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	500	30
"	"	2[40] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	1200	60
60	21/2 09	10[00] a. m.	36°02′	5°15′	900	s. cl.	Cloudy	ESE	6	ESE	6	18°6	14°5	20.18	36.45	Hy	850—0	"
																P 100	Surf.	5
"	"	11[20] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 30	Surf.	5
61	21/2 09	1[00] p. m.	35°57′	5°35′	740	st.	Cloudy	ESE	6	ESE	4	18°0	14°65	20.21	36.51	Hy	700—0	"
"	"	3[25] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	600	60
																P 100	Surf.	5
"	"	3[30] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 30	Surf.	5

Station Nr.	Date	Hour	Position Lat. N.	Position Long. W.	Depth Meters	Nature of bottom	Weather	Wind Direction 0—12	Wind Force 0 12	Sea Direction 0 12	Sea Force 0—12	Temperature Air	Temperature Surface	Surface Cl ‰	Surface S ‰	Gear	Wire out Meters	Duration of haulin minutes
Atlantic.																		
62	21/2 09	6[00] p. m.	35°45′	5°59′	58	st. sh.	Cloudy	ESE	6	ESE	3	14°2	14°9	20.11	36.33	Hy	50—0	"
"	"	8[26] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	100	30
"	"	8[40] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 30	Surf.	5
"	"	9[10] p. m.	"	"	"	"		"	"	"	"	"	"	"	"	P 100	Surf.	5
63	21/2 09	11[30] p. m.	35°50′	6°03′	490	st.	Cloudy	ESE	7	ESE	6	"	"	"	"	Y 200	25	30
"	22/2 09	0[05] a. m.	14°0	14°95	20.08	36.27	Hy	475—0	"									
"	"	1[45] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	30
64	22/2 09	8[15] a. m.	36°32′	6°26′	40	m.	Overcast	ESE	5	ESE	4	"	"	"	"	Y 200	600	60
"	"	9[00] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	30
"	"	9[10] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	80	60
"	"	9[00] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 30	Surf.	5
65	24/2 09	5[50] a. m.	35°53′	7°26′	1300	m.	Squally	W	4	W	4	14°5	14°0	20.05	36.22	P 100	Surf.	5
"	"	6[30] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Hy	40—0	"
"	"	7[45] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	30
"	"	10[00] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	65	60
"	"	0[00] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	120
"	"	4[00] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	600	120
"	"	6[30] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	1600	120
66	25/2 09	1[05] a. m.	36°16′	6°52′	735	s.	Cloudy	N	3	N	4	16°0	15°78	20.13	36.36	Hy	1250—0	"
"	"	1[45] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	65	60
"	"	2[55] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	30
"	"	5[15] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	65	60
"	"	7[00] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	120
"	"	8[30] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	600	120
67	22/2 09	p. m.	Cadiz Road		6	s. m.	Cloudy	ESE	8	0	"	15°2	14°8	20.07	36.26	Hy	700 0	"
"	"	"	Cadiz Harbour		0—1	st.	"	"	"	"	"	"	"	"	"	Y 200	1200	120
68	27/2 09	5[00] p. m.	36°39′	7°21′	550	m.	Clear	ENE	2	SE	2	"	"	"	"	P 30	Surf.	5
"	"	5[30] p. m.	"	"	"	"	"	"	"	"	"	14°2	14°8	20.06	36.24	Hy	535—0	"
"	"	7[00] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	800	45
69	28/2 09	3[05] p. m.	36°13′	9°11′	>3500	"	Cloudy	NNW	4	NW	5	"	"	"	"	Y 200	65	30
"	"	5[00] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 30	Surf.	5
"	"	6[30] p. m.	"	"	"	"	"	"	"	"	"	15°0	14°79	20.07	36.26	Y 200	300	30
"	"	9[00] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Hy	2000—0	"
"	"	10[43] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	C 200	3000	60
"	"	11[40] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	600	60
"	1/3 09	0[30] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	65	30
70	4/3 09	9[00] a. m.	39°06′	9°47′	94	st.	Squally	NW	3	NNW	3	"	"	"	"	Y 200	300	30
71	4/3 09	1[30] p. m.	39°33′	9°45′	>1300	"	Squally	NW	3	NNW	3	"	"	"	"	Y 200	25	30
"	"	4[00] p. m.	"	"	"	"	"	"	"	"	"	13°4	14°5	"	"	P 30	Surf.	5
"	"	6[25] p. m.	"	"	"	"	"	"	"	"	"	9°6	12°76	19.84	35.84	Y 200	65	60
"	"	8[40] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Hy	1150—0	"
"	"	10[50] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	1600	120
"	5/3 09	0[00] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	600	120
72	7/3 09	p. m.	Ferrol Harbour		21	s. sh.	Squally	NNW	8	NW	1	"	"	"	"	Y 200	300	120
73	8/3 09	3[50] p. m.	43°46′	8°11′	180	s.	Rain	W	3	NW	6	9°3	11°8	"	"	Y 200	65	60
74	8/3 09	10[00] p. m.	44°21′	7°55′	>3000	"	Overcast	W	2	NW	6	10°4	11°5	19.72	35.62	Y 200	65	60
"	"	10[50] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	D 1	5 hauls	"
"	9/3 09	0[10] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Hy	1150 0	"
"	"	1[30] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	60
"	"	2[40] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	600	60
75	9/3 09	1[45] p. m.	45°37′	7°03′	>1000	"	Cloudy	NW	1	NW	5	"	"	"	"	Y 200	65	60
"	"	5[00] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	30
"	"	6[30] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	C 200	4300	120
"	"	7[45] p. m.	"	"	"	"	Squally	SE	1	"	"	10°00	11°4	19.71	35.61	Hy	1150 0	"
"	"	9[00] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	600	60
"	"	10[15] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	60
76	10/3 09	11[30] a. m.	47°01′	5°48′	>1200	"	Cloudy	NE	3	NW	5	"	"	"	"	Y 200	65	60
"	"	1[15] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	30
"	"	2[40] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	60
"	"	4[00] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	600	60
"	"	6[05] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	1600	60
"	"	7[15] p. m.	"	"	"	"	"	"	"	"	"	9°00	10°78	19.66	35.52	Hy	1150—0	"
77	11/3 09	3[15] p. m.	48°43′	4°45′	100	"	Cloudy	E	4	ENE	5	"	"	"	"	Y 200	65	60
78	12/3 09	3[35] p. m.	51°01′	1°35′E	49	"	Cloudy	N	3	ENE	4	8°0	8°8	"	"	Y 200	25	30
												3°0	3°2	"	"	Y 200	65	30

b. Summer Expedition.

Station Nr.	Date	Hour	Position Lat. N.	Position Long. W.	Depth Meters	Nature of bottom	Weather	Wind Direction 0—12	Wind Force 0—12	Sea Direction 0—12	Sea Force 0—12	Temperature Air	Temperature Surface	Surface Cl ‰	Surface S ‰	Gear	Wire out Meters	Duration of haulin minutes
Atlantic.																		
79	13/6 10	8[40] a. m.	47°30′	6°43′	>150	"	Cloudy	NNW	3	NW	7	17°5	13°90	19.58	35.37	Y 200	65	15
"	"	8[45] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
80	13/6 10	7[00] p. m.	46°17′	7°31′	>4000	"	Clear	0	"	W	3	15°0	15°41	19.69	35.57	Hy	2000—0	180
"	"	10[00] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	65	30
"	"	10[05] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	10[45] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	30
"	"	11[30] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	15
81	15/6 10	4[00] p. m.	41°32′	9°32′	2140	s. m.	Cloudy	0	"	N	3	"	"	"	"	Y 200	300	30
																N 30	100	30
"	"	4[05] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
		4[10] p. m.														N 30	Surf.	10
"	"	4[50] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	500	30
"	"	6[00] p. m.	"	"	"	"	"	"	"	"	"	19°0	17°94	19.61	35.43	Hy	2000—0	225
82	16/6 10	4[40] a. m.	40°47′	9°29′	>1000	"	Overcast	0	"	N	3	20°5	15°85	19.59	35.39	T 25	Surf.	"
83	16/6 10	0[30] p. m.	39°46′	9°26′	>100	"	Clear	0	"	N	2	20°5	17°68	19.63	35.46	T 25	Surf.	"
84	16/6 10	3[35] p. m.	39°22′	9°23′	30	st.	Clear	W	2	W	1	"	"	"	"	Y 200	55	30
"	"	3[50] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	4[30] p. m.	"	"	"	"	"	"	"	"	"	22°0	17°0	19.74	35.66	Hy	28—0	"
"	"	5[15] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	45	30
85	17/6 10	2[00] a. m.	38°22′	9°28′	>700	"	Clear	0	"	W	1	18°0	16°75	19.70	35.59	Y 200	65	15
																N 30	Surf.	5
"	"	2[05] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
86	17/6 10	11[00] a. m.	37°22′	9°15′	>700	"	Misty	NE	1	NE	1	20°5	17°98	19.87	35.90	P 30	Surf.	"
87	17/6 10	1[30] p. m.	37°03′	9°15′	1580	st.	Clear	N by W	1	WNW	3	20°0	17°06	19.84	35.84	Hy	1500—0	105
"	"	4[00] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	30
"	"	4[00] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	245	30
"	"	4[40] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	65	15
"	"	4[45] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf	10
88	17/6 10	9[00] p. m.	36°46′	8°48′	>300	"	Clear	N	4	N	3	19°5	18°62	20.14	36.38	P 30	Surf.	"
89	18/6 10	1[00] a. m.	36°28′	8°22′	1310	m.	Clear	NNE	2	N	3	18°0	18°98	20.14	36.38	Hy	1250—0	105
"	"	3[00] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	65	15
"	"	3[25] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	30
"	"	3[30] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	4[10] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	1000	30
90	18/6 10	8[45] a. m.	36°10′	7°53′	>1000	"	Clear	ENE	4	ENE	3	21°5	19°45	20.16	36.42	P 30	Surf.	"
91	18/6 10	3[00] p. m.	35°53′	7°26′	1225	m.	Clear	E by S	6	E by S	6	22°0	19°08	20.19	36.47	Hy	1200—0	120
																Y 200	1600	60
"	"	5[25] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
"	"	5[30] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	6[55] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	45
92	19/6 10	3[30] a. m.	36°16′	6°50′	>500	"	Clear	E by S	6	E by S	6	20°5	18°01	20.04	36.20	Y 200	65	30
"	"	3[45] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	4[45] a. m.	"	"	775	"	"	"	"	"	"	"	"	"	"	Hy	750—0	75
93	22/6 10	9[20] p. m.	36°17′	6°17′	40	"	Clear	0	"	W by S	2	19°0	19°14	19.95	36.04	Y 200	50	30
																N 30	Surf.	10
"	"	9[25] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
94	23/6 10	0[35] a. m.	36°06′	6°02′	65	"	Clear	SW	2	NW	3	18°0	18°48	19.97	36.08	Y 200	65	30
																N 30	Surf.	10
"	"	0[40] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	1[30] a. m.	"	"	"	"	"	"	"	"	"	19°0	18°48	19.97	36.08	Hy	60—0	"
95	23/6 10	4[00] a. m.	35°57′	6°00′	275	m.	Clear	SW	3	SW	3	18°0	17°80	20.04	36.20	Hy	265—0	60
"	"	5[10] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	30
"	"	5[15] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	5[50] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	65	30
"	"	6[25] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	15
96	23/6 10	9[30] a. m.	35°48′	5°58′	185	m.	Clear	SW	3	SW	3	"	"	"	"	Y 200	65	30
"	"	9[40] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	10[50] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	D 1	300	"
"	"	11[00] a. m.	"	"	"	"	"	"	"	"	"	17°0	17°58	20.05	36.22	Hy	180—0	"
97	23/6 10	1[00] p. m.	35°50′	5°59′	598	m.	Clear	E	1	W	3	19°0	18°36	20.01	36.15	Hy	575—0	80
																T 25	Surf.	"
Mediterranean (Western Basin).																		
98	25/6 10	5[00] p. m.	35°57′	5°35′	700	st.	Clear	ENE	4	E	3	20°0	17°96	19.95	36.04	Hy	700—0	80
"	"	6[35] p. m.	"	"	775	"	"	"	"	"	"	"	"	"	"	Y 200	65	15
																N 30	Surf.	10
"	"	6[40] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10

Station Nr.	Date	Hour	Position Lat. N.	Position Long.	Depth Meters	Nature of bottom	Weather	Wind Direction 0—12	Wind Force 0—12	Sea Direction 0—12	Sea Force 0—12	Temperature Air	Temperature Surface	Surface Cl ‰	Surface S ‰	Gear	Wire out Meters	Duration of haul in minutes
99	28/6 10	9[00] p. m.	36°02′	W 5°16′	1150 700	m.	Foggy	E	1	E	1	19°0	16°80	20.07	36.26	Hy	1000 0	130
"	"	11[25] p. m.	"	"	750	"	"	"	"	"	"	"	"	"	"	Y 200	300	30
																P 100	Surf.	10
"	"	11[35] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
"	24/6 10	0[10] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	65	15
100	24/6 10	4[25] a. m.	36°10′	4°42′	> 1100	"	Overcast	E	3	E	3	20°0	19°88	20.12	36.35	P 30	Surf.	"
101	24/6 10	8[15] a. m.	36°19′	4°06′	> 1000	"	Overcast	E by S	2	E	2	21°5	18°49	20.77	37.52	P 30	Surf.	"
102	24/6 10	0[15] p. m.	36°26′	3°33′	> 600	"	Misty	SE	2	E	2	26°5	20°60	20.08	36.27	P 30	Surf.	"
103	24/6 10	4[00] p. m.	36°34′	2°55′	> 800	"	Clear	ESE	1	E	1	29°3	21°29	20.18	36.45	P 30	Surf.	"
104	24/6 10	6[20] p. m.	36°37′	2°04′	250	m.	Clear	ESE	1	E	1	24°0	22°10	"	"	Y 200	65	30
"	"	6[25] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
105	24/6 10	7[45] p. m.	36°43′	2°08′	20	st.	Clear	0	0	0	0	21°0	20°40	20.27	36.62	Y 200	40	15
"	"	7[50] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
"	"	8[15] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	D 2	50	10
106	24/6 10	11[00] p. m.	36°33′	2°00′	ca. 1100	m.	Clear	0	0	0	0	20°5	20°92	20.24	36.56	Hy	1000 0	"
"	25/6 10	0[20] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	1200	60
"	"	0[25] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	1[45] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	30
"	"	2[30] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	65	30
107	25/6 10	7[30] a. m.	36°18′	1°14′	ca. 2250	"	Clear	0	0	0	0	"	"	"	"	Y 200	2000	60
"	"	7[40] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	9[05] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	30
"	"	9[50] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	65	30
"	"	10[30] a. m.	"	"	"	"	"	"	"	"	"	21°06	21°26	20.44	36.92	Hy	2000 0	270
108	25/6 10	8[30] p. m.	36°03′	0°27′	> 2400	"	Misty	W	1	E	1	20°5	21°00	20.22	36.53	Hy	1500 0	90
"	"	10[30] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	30
																P 100	Surf.	10
"	"	10[40] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
"	"	11[15] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	65	30
"	"	11[55] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	15
"	26/6 10	0[40] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	2000	60
109	26/6 10	6[20] a. m.	36°19′	E 0°10′	> 175	"	Clear	W	1	W	1	23°5	20°61	20.23	36.55	P 30	Surf.	"
110	26/6 10	10[30] a. m.	36°27′	0°54′	> 25	"	Clear	W	1	W	1	26°5	20°79	20.25	36.58	P 30	Surf.	"
111	26/6 10	3[00] p. m.	36°42′	1°32′	> 300	"	Clear	W	3	W	3	26°0	21°15	"	"	P 30	Surf.	"
112	26/6 10	9[00] p. m.	36°56′	2°15′	ca. 2600	"	Clear	N	1	W	2	22°4	21°96	20.59	37.19	Hy	2000 0	180
																Y 200	300	30
"	27/6 10	0[15] a. m.	"	"	2700	m.	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
"	"	0[20] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	1[05] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	65	15
"	"	1[30] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	15
113	28/6 10	2[00] a. m.	36°53′	3°09′	815	m.	Clear	NE	1	NE	4	18°5	20°96	20.27	36.62	Hy	400—0	70
																Y 200	300	30
"	"	3[25] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
114	28/6 10	1[20] p. m.	37°45′	3°48′	> 2600	"	Clear	E	2	E	2	24°0	22°29	20.60	37.21	P 30	Surf.	"
115	28/6 10	8[00] p. m.	38°17′	4°11′	2800	m.	Clear	SE	1	SE	1	23°0	21°92	20.65	37.30	Hy	2500—0	180
"	"	11[20] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	30
																P 100	Surf.	10
"	"	11[30] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
"	29/6 10	0[30] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	2000	60
"	"	1[20] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	65	15
"	"	1[40] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	15
116	29/6 10	4[05] p. m.	39°27′	5°26′	2860	m.	Clear	ESE	1	E	1	"	"	"	"	Y 200	300	30
"	"	4[20] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
"	"	7[00] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	10[00] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	D 1	3600	120
"	30/6 10	1[40] a. m.	"	"	"	"	"	SE	1	SE	1	20°9	21°90	20.81	37.59	Hy	2400—0	200
												"	"	"	"	Y 200	300	30
"	"	1[50] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
"	"	2[30] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	3[00] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	65	30
117	30/6 10	11[30] a. m.	40°15′	6°12′	> 3000	"	Clear	E	1	E	1	25°0	20°98	20·82	37.61	Y 200	25	15
																P 30	Surf.	"
118	30/6 10	5[55] p. m.	41°00′	6°43′	> 2700	"	Clear	NW	3	N	2	"	"	"	"	Y 200	300	30
"	"	6[05] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
"	"	7[00] p. m.	"	"	"	"	"	"	"	"	"	21°0	20°73	20.85	37.66	P 100	Surf.	10
																Hy	2500 0	220
"	"	10[55] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	30
"	"	11[05] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
"	"	11[35] p. m.	"	"	"	"	"	"	"	"	"	20°5	"	"	"	P 100	Surf.	10
																Y 200	65	30

Station Nr.	Date	Hour	Position Lat. N.	Position Long. E.	Depth Meters	Nature of bottom	Weather	Wind Direction 0—12	Wind Force 0—12	Sea Direction 0—12	Sea Force 0—12	Temperature Air	Temperature Surface	Surface Cl ‰	Surface S ‰	Gear	Wire out Meters	Duration of haul in minutes
118	1/7 10	0[20] a. m.	41°00′	6°43′	> 2700	m.	Clear	NW	3	N	2	20°5	20°77	20.85	37.66	Y 200	25	15
119	1/7 10	0[20] p. m.	42°02′	7°20′	> 2500	"	Clear	WNW	6	NW	6	19°5	19°20	21.15	38.21	P 30	Surf.	"
120	1/7 10	4[45] p. m.	42°31′	7°41′	ca. 2700	"	Clear	W by S	7	W	7	18°7	18°36	21.19	38.28	Hy	2500—0	195
"	"	8[50] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	30
"	"	8[55] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
121	2/7 10	3[05] a. m.	43°08′	8°05′	> 2500	"	Cloudy	SW	5	WSW	5	18°5	18°24	21.19	38.28	Y 200	25	30
122	2/7 10	10[00] a. m.	43°50′	8°34′	1285	"	Cloudy	W	3	SW	3	"	"	"	"	Y 200	600	60
																N 30	Surf.	10
"	"	10[15] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	11[30] a. m.	"	"	"	"	"	"	"	"	"	19°4	19°46	21.20	38.30	Hy	1300—0	270
"	"	5[30] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	1200	30
123	2/7 10	11[00] p. m.	44°14′	8°55′	ca. 700	"	Cloudy	SSE	3	S	3	19°5	20°26	20.98	37.90	Hy	600—0	60
"	3/7 10	0[05] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	30
"	"	0[55] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	65	30
"	"	1[05] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	1[50] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	15
"	"	2[30] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	10	15
124	3/7 10	3[30] a. m.	44°20′	9°05′	86	"	Cloudy	SE	4	SW	3	20°0	20°5	"	"	Y 200	65	90
125	9/7 10	8[00] p. m.	43°54′	9°13′	1082	m.	Cloudy	SW	1	W	2	19°0	19°06	21.23	38.35	Hy	1050—0	90
"	"	9[45] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	30
																Y 200	25	30
"	"	10[30] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
"	"	10[40] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
126	10/7 10	12[00] a. m.	42°43′	9°50′	588	cl.	Cloudy	S by W	2	SW	2	"	"	"	"	L	"	360
"	"	1[30] p. m.	"	"	"	"	"	"	"	"	"	20°4	21°66	21.01	37.95	Hy	580—0	120
"	"	4[00] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 50	80—0	"
"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	N 50	206—100	"
"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	N 50	500—200	"
																Y 200	300	30
"	"	9[30] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	275	30
																Y 200	25	30
"	"	10[10] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
"	"	10[20] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
127	11/7 10	7[00] a. m.	41°47′	10°22′	> 1000	"	Misty	WSW	2	SW	4	20°5	18°88	21.24	38.37	P 30	Surf.	"
128	11/7 10	2[00] p. m.	41°01′	10°53′	1630	cl.	Cloudy	WSW	1	SW	3	"	"	"	"	D 1	1800	240
																N 30	100—0	"
"	"	2[30] p. m.	"	"	"	"	"	"	"	"	"	20°8	20°27	21.15	38.21	Hy	1500—0	165
129	12/7 10	3[00] a. m.	40°05′	11°31′	3420	cl.	Clear	SE	1	S	1	"	"	"	"	Y 200	25	30
"	"	3[10] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
"	"	3[40] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	4[20] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	30
"	"	6[00] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	1000	60
"	"	11[00] a. m.	"	"	"	"	"	E	1	E	2	21°6	21°76	21.06	37.95	Hy	3200—0	300
"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	N 50	80—0	"
"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	N 50	200—90	"
"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	N 50	1100—0	"
																C 200	3500	120
"	"	3[00] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
"	"	3[15] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	8[00] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	600	30
130	13/7 10	0[50] a. m.	39°35′	11°20′	> 3000	"	Cloudy	ESE	3	SE	3	17°0	21°53	20.98	37.90	Y 200	25	30
"	"	1[00] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
131	13/7 10	9[50] a. m.	38°36′	11°00′	915	m.	Misty	S	1	S	2	"	"	"	"	Y 200	25	30
																N 30	Surf.	10
"	"	10[05] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	10[35] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	30
"	"	10[40] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	1000	60
"	"	2[00] p. m.	"	"	921	"	"	"	"	"	"	25°0	21°48	21.02	37.97	Hy	900—0	180
132	14/7 10	0[55] a. m.	38°57′	9°47′	1227	cl.	Clear	0	0	0	0	"	"	"	"	Y 200	1500	60
																N 30	Surf.	10
"	"	1[10] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	3[05] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	30
"	"	3[45] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	30
"	"	4[50] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	600	30
"	"	6[00] a. m.	"	"	1650	"	"	"	"	"	"	19°0	20°46	21.04	38.01	Hy	1500—0	135
"	"	9[00] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 50	200—95	"
"	"	10[00] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 50	600—200	"
"	"	11[00] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 50	1100—600	"
"	"	12[00] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 50	95—0	"
133	14/7 10	6[00] p. m.	38°18′	9°59′	602	cl.	Clear	0	0	0	0	"	"	"	"	D 1	800	180
"	"	6[15] p. m.	"	"	"	"	"	"	"	"	"	22°2	21°82	21.04	38.01	Hy	590—0	120

Station Nr.	Date	Hour	Position Lat. N.	Position Long. E.	Depth Meters	Nature of bottom	Weather	Wind Direction 0—12	Wind Force 0—12	Sea Direction 0—12	Sea Force 0—12	Temperature Air	Temperature Surface	Surface Cl ‰	Surface S ‰	Gear	Wire out Meters	Duration of haul in minutes
133	14/7 10	9^{20} p. m.	38°18′	9°59′	602	cl.	Clear	"	0	0	0	22°2	21°82	21.04	38.01	Y 200	600	30
"	"	9^{30} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
"	"	10^{15} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	11^{00} p m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	30
																Y 200	25	30
134	15/7 10	4^{50} a. m.	37°37′	10°17′	350	m.	Clear	SSE	1	S	1	"	"	"	"	Y 200	25	30
"	"	5^{00} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
"	"	5^{40} a. m.	"	"	400	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	6^{45} a. m.	"	"	410	"	"	"	"	"	"	"	"	"	"	Y 200	300	30
"	"	8^{25} a. m.	"	"	405	"	"	"	"	"	"	"	"	"	"	D 1	500	30
"	"	9^{00} a. m.	"	"	395	"	"	"	"	"	"	"	"	"	"	M	600	30
"	"	0^{30} p. m.	"	"	"	"	"	"	"	"	"	25°0	22°60	20.55	37.12	Hy	385—0	90
"	"	0^{45} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 50	75—0	"
"	"	1^{00} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 50	125 75	"
"	"	1^{30} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 50	200 125	"
																N 50	350—185	"
135	15/7 10	11^{30} p. m.	37°17′	10°28′	174	"	Clear	0	0	0	0	22°0	22°92	20.55	37.12	Hy	170—0	60
																Y 200	25	30
"	16/7 10	0^{55} a. m.	"	"	200	m.	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
"	"	1^{05} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
136	19/7 10	3^{10} a. m.	37°01′	10°31′	80	m.	Cloudy	NNE	3	NE	2	21°0	22°90	20.52	37.07	Y 200	25	30
"	"	3^{20} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
"	"	3^{50} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
																Y 200	100	30
																Y 200	25	30
137	19/7 10	8^{15} a. m.	37°17′	10°56′	190	cl.	Cloudy	NW	3	SE	2	"	"	"	"	N 30	Surf.	10
"	"	8^{25} a. m.	"	"	175	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	9^{05} a. m.	"	"	195	"	"	"	"	"	"	"	"	"	"	Y 200	250	30
"	"	10^{00} a. m.	"	"	"	"	"	"	"	"	"	22°0	22°76	20.63	37.27	Hy	180 —0	60
"	"	11^{25} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	D 1	250	15
138	19/7 10	4^{40} p. m.	37°37′	11°25′	820	cl.	Cloudy	NW	1	SE	1	"	"	"	"	D 1	1000	120
"	"	4^{45} p. m.	"	"	788	"	"	"	"	"	"	23°0	23°50	20.80	37.57	Hy	775—0	135
"	"	7^{40} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	1000	60
																Y 200	300	60
"	"	9^{10} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
"	"	9^{20} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	9^{50} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	30
139	20/7 10	1^{40} a. m.	37°57′	11°54′	680	m.	Overcast	NW	1	W	1	22°3	21°96	20.70	37.39	Y 200	25	30
																N 30	Surf.	10
"	"	2^{00} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	2^{25} a. m.	"	"	530	"	Cloudy	WNW	2	W	1	"	"	"	"	Y 200	300	30
"	"	3^{40} a. m.	"	"	580	"	"	"	"	"	"	"	"	"	"	Y 200	800	60
"	"	5^{50} a. m.	"	"	610	"	"	"	"	"	"	"	"	"	"	D 1	800	120
"	"	6^{00} a. m.	"	"	ca. 700	"	"	"	"	"	"	"	"	"	"	Hy	700—0	120

Mediterranean (Eastern Basin).

140	20/7 10	2^{05} p. m.	37°29′	12°34′	112	cl.	Clear	NW	4	NW	4	23°3	22°70	20.82	37.61	D 1	250	20
																N 30	Surf.	10
"	"	2^{15} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
141	20/7 10	10^{35} p. m.	36°42′	13°34′	530	m.	Clear	NW	6	NW	5	"	"	"	"	Y 200	25	15
"	"	10^{40} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	11^{00} p. m.	"	"	ca. 500	"	"	"	"	"	"	24°0	23°80	20.79	37.56	Hy	475 0	60
142	22/7 10	2^{50} a. m.	35°44′	15°07′	98	f. s.	Clear	N	1	N	3	"	"	"	"	Y 200	25	30
"	"	3^{00} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	3^{40} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	150	30
"	"	4^{40} a. m.	"	"	98	"	"	"	"	"	"	"	"	"	"	D 1	200	60
"	"	4^{40} a. m.	"	"	"	"	"	"	"	"	"	22°5	24°05	20.78	37.54	Hy	95—0	60
"	"	6^{00} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	M	250	30
143	22/7 10	5^{15} p. m.	35°18′	16°25′	1842	"	Clear	NE	1	0	0	"	"	"	"	D 1	2000	180
"	"	5^{20} p. m.	"	"	"	"	"	"	"	"	"	25°2	25°26	21.04	38.01	Hy	1800 0	190
"	23/7 10	0^{30} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	30
"	"	0^{40} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	1^{20} a. m.	"	"	"	"	"	NNE	2	NE	3	"	"	"	"	Y 200	25	30
"	"	2^{00} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	1000	60
144	23/7 10	6^{45} p. m.	34°31′	18°40′	3340	"	Clear	NNE	1	NE	3	"	"	"	"	D 2	4000	300
"	"	7^{20} p. m.	"	"	"	"	"	"	"	"	"	25°5	26°05	21.31	38.49	Hy	3200—0	300
"	24/7 10	2^{00} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	30
"	"	2^{10} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	2^{45} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	30
"	"	3^{45} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	2000	60

Station Nr.	Date	Hour	Position Lat. N.	Position Long. E.	Depth Meters	Nature of bottom	Weather	Wind Direction 0—12	Wind Force 0—12	Sea Direction 0—12	Sea Force 0—12	Temperature Air	Temperature Surface	Surface Cl ‰	Surface S ‰	Gear	Wire out Meters	Duration of haul in minutes
144	24/7 10	6^{20} a. m.	34°31′	18°40′	3340	f. s.	Clear	NNE	1	NE	3	25°5	26°05	21.31	38.49	C 200	4000	60
"	"	9^{00} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	30
"	"	10^{10} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	D 1	4000	120
145	25/7 10	3^{30} a. m.	32°38′	19°02′	"	"	Cloudy	NW	3	NW	4	"	"	"	"	Y 200	25	30
"	"	3^{40} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	4^{10} a. m.	"	"	1925	s. cl.	"	"	"	"	"	"	"	"	"	Y 200	300	30
"	"	5^{45} a. m.	"	"	"	"	"	N	5	N	5	"	"	"	"	D 1	2500	300
"	"	6^{00} a. m.	"	"	"	"	"	"	"	"	"	25°2	25°36	21.32	38.51	Hy	1800—0	180
146	25/7 10	4^{00} p. m.	31°59′	19°02′	> 1000	"	Cloudy	N	5	N	5	31°5	25°2	"	"	P 30	Surf.	"
147	25/7 10	7^{45} p. m.	31°35′	19°02′	960	cl.	Cloudy	N	5	N	5	"	"	"	"	D 1	1200	180
"	"	8^{00} p. m.	"	"	993	"	"	"	"	"	"	25°0	25°20	21.15	38.21	Hy	950—0	120
																Y 200	25	30
"	"	11^{35} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
"	"	11^{40} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	26/7 10	0^{20} a. m.	"	"	"	"	"	N	4	NW	4	"	"	"	"	Y 200	300	30
"	"	1^{10} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	1000	60
148	26/7 10	9^{00} a. m.	30°45′	19°02′	290	cl.	Cloudy	N	3	NW	3	"	"	"	"	D 1	400	120
																Hy	275—0	90
"	"	9^{00} a. m.	"	"	"	"	"	"	"	"	"	25°0	24°70	21.25	38.39	N 30	Surf.	10
"	"	10^{55} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
149	26/7 10	0^{30} p. m.	30°30′	19°02′	80, 75	s.	Cloudy	N	3	NW	3	28°0	25°80	"	"	D 1	200	30
150	26/7 10	2^{10} p. m.	30°23′	19°02′	35	sh. s.	Cloudy	N	3	NW	3	"	"	"	"	D 1	90	15
"	"	2^{30} p. m.	"	"	"	"	"	"	"	"	"	25°1	25°57	21.21	38.31	Hy	32—0	30
"	"	3^{15} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	M	200	30
"	"	4^{00} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	M	200	15
151	27/7 10	1^{00} p. m.	32°31′	20°18′	> 40	"	Clear	N	3	NW	4	26°5	23°9	21.27	38.42	P 30	Surf.	"
152	27/7 10	10^{50} p. m.	33°11′	21°44′	> 2200	"	Cloudy	NNW	4	N	4	"	"	"	"	Y 200	25	15
																N 30	Surf.	10
"	"	11^{00} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	11^{35} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	30
"	"	11^{35} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	250	30
"	28/7 10	0^{30} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	1000	60
"	"	0^{30} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	950	60
"	"	3^{00} a. m.	"	"	ca. 2100	"	"	"	"	"	"	23°8	24°34	21.38	38.62	Hy	2000—0	240
153	28/7 10	1^{30} p. m.	32°45′	22°41′	13	s.	Cloudy	NNW	3	N	4	24°0	24°35	"	"	D 1	25	10
"	"	1^{30} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
154	29/7 10	3^{30} a. m.	32°10′	24°46′	365	cl.	Clear	NNW	4	NW	5	"	"	"	"	Y 200	25	30
																N 30	Surf.	10
"	"	3^{40} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	4^{30} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	30
"	"	5^{00} a. m.	"	"	300	"	"	"	"	"	"	24°0	24°60	21.41	38.68	Hy	280—0	90
155	29/7 10	3^{00} p. m.	32°16	26°03′	> 2000	"	Cloudy	NNW	3	NW	4	25°5	25°4	21.55	38.93	P 30	Surf.	"
156	29/7 10	8^{00} p. m.	"	"	ca. 3200	"	Clear	NW	4	NW	4	25°0	25°49	21.61	39.04	Hy	3000—0	240
"	30/7 10	0^{40} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	1000	60
"	"	0^{40} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	950	60
																Y 200	25	30
"	"	2^{15} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
"	"	2^{25} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	3^{00} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	600	30
																Y 200	300	30
"	"	3^{50} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	250	30
157	30/7 10	3^{50} p. m.	33°16′	27°18′	> 2700	"	Clear	NW	5	NW	6	28°0	25°4	21.64	39.09	P 30	Surf.	"
158	31/7 10	5^{10} a. m.	34°23′	27°57′	> 2000	"	Clear	NNW	7	NNW	7	24°4	24°08	21.69	39.18	Hy	2000—0	135
"	"	7^{00} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
"	"	7^{30} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
159	31/7 10	8^{00} p. m.	35°31′	27°55′	> 1000	"	Clear	NNW	5	NNW	5	24°0	24°72	21.72	39.23	Y 200	300	30
																P 30	Surf.	"
160	1/8 10	2^{00} a. m.	35°59′	28°14′	"	"	Clear	0	"	NW	1	"	"	"	"	Y 200	25	30
																N 30	Surf.	10
"	"	2^{10} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	2^{45} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	30
"	"	3^{35} a. m.	"	"	"	"	"	SW	2	SW	2	"	"	"	"	Y 200	1000	60
"	"	6^{20} a. m.	"	"	3200	cl.	"	W	2	N	3	"	"	"	"	D 1	3700	480
"	"	6^{30} a. m.	"	"	2980	"	"	"	"	"	"	26°2	26°28	21.71	39.22	Hy	2975—0	240
"	"	10^{30} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 50	30—0	"
"	"	10^{45} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 50	100—30	"
"	"	11^{30} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 50	200—100	"
"	"	0^{15} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 50	1000-200	"
"	"	2^{20} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	30
"	"	3^{30} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	C 200	4000	60
																Y 200	25	30
161	2/8 10	3^{00} a. m.	36°12′	27°16′	> 1000	"	Clear	NW	5	NW	5	24°2	23°76	21.67	39.13	N 30	Surf.	10

Station Nr.	Date	Hour	Position Lat. N.	Position Long. E.	Depth Meters	Nature of bottom	Weather	Wind Direction 0—12	Wind Force 0—12	Sea Direction 0—12	Sea Force 0—12	Temperature Air	Temperature Surface	Surface Cl ‰	Surface S ‰	Gear	Wire out Meters	Duration of haul in minutes
161	$^{2}/_{8}$ 10	3^{10} a. m.	36°12′	27°16′	~ 1000	cl.	Clear	NW	5	NW	5	24°2	23°76	21.67	39.13	P 100	Surf.	10
162	$^{2}/_{8}$ 10	4^{00} p. m.	37°24′	26°49′	> 80	"	Clear	NNW	4	NNW	2	22°0	26°0	21.66	39.13	P 30	Surf.	"
163	$^{2}/_{8}$ 10	9^{15} p. m.	37°52′	26°22′	1170	cl.	Clear	NW	1	NW	2	"	"	"	"	D 1	1300	120
"	"	9^{20} p. m.	"	"	"	"	"	"	"	"	"	23°7	26°6	21.66	39.13	Hy	1140—0	105
																N 30	80—0	"
"	$^{3}/_{8}$ 10	0^{05} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	1000	30
"	"	1^{05} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	200	15
"	"	1^{40} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	15
																N 30	Surf.	10
"	"	1^{45} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
164	$^{3}/_{8}$ 10	10^{00} a. m.	38°40′	26°34′	> 75	"	Clear	ENE	1	ENE	1	27°0	24°4	21.61	39.04	P 30	Surf.	"
165	$^{5}/_{8}$ 10	7^{35} a. m.	39°48′	25°59′	35	s.	Clear	ENE	1	ENE	1	26°5	24°5	19.67	35.53	D 1	50	20
"	"	7^{45} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 30	Surf.	10
166	$^{5}/_{8}$ 10	9^{15} a. m.	39°47′	26°03′	11—15	s.	Clear	ENE	1	ENE	1	27°0	24°5	"	"	D 1	30	20
167	$^{5}/_{8}$ 10	10^{20} a. m.	39°49′	26°06	15—19	s.	Clear	ENE	1	ENE	1	27°5	24°5	"	"	D 1	40	20
"	"	11^{15} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
							Dardanelles, Sea of Marmora, Bosphorus, Black Sea.											
168	$^{5}/_{8}$ 10	7^{30} p. m.	40°16′	26°34′	> 80	"	Clear	NNE	3	NE	2	28°0	25°02	12.43	22.47	P 30	Surf.	"
169	$^{6}/_{8}$ 10	4^{40} a. m.	40°45′	27°51′	> 800	"	Clear	NE	2	NE	2	25°0	24°64	11.83	21.38	P 30	Surf.	"
170	$^{6}/_{8}$ 10	0^{35} p. m.	40°46′	28°57′	1235	m.	Clear	0	"	0	"	26°0	24°8	11.90	21.51	Hy	1200—0	135
"	"	2^{50} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 50	20—0	"
"	"	3^{00} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 50	80—20	"
"	"	3^{20} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 50	200—85	"
"	"	4^{00} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 50	1000-195	"
"	"	4^{20} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
171	$^{10}/_{8}$ 10	3^{25} p. m.	41°07′	29°05′	60	m.	Clear	SW	2	SW	1	"	"	"	"	Y 200	50	15
"	"	3^{30} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	3^{45} p. m.	"	"	"	"	"	"	"	"	"	26°0	23°2	9.95	17.99	Hy	58—0	45
172	$^{10}/_{8}$ 10	10^{30} p. m.	41°32′	29°24′	1090	cl.	Clear	SE	1	SE	1	23°5	24°1	9.73	17.59	Hy	1000—0	90
"	"	10^{10} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	D 1	1300	210
"	$^{11}/_{8}$ 10	0^{00} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 50	17—0	"
"	"	0^{25} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 50	50—17	"
"	"	1^{00} a. m.	"	"	"	"	"	"	"	"	"	"	"		"	N 50	200—50	"
																Y 200	600	20
"	"	2^{10} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
"	"	2^{15} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	2^{50} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	100	15
"	"	3^{25} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	50	15
"	"	3^{50} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	10	15
173	$^{11}/_{8}$ 10	6^{00} a. m.	41°17′	29°11′	65	st.	Clear	SW	1	SW	1	29°0	24°25	9.78	17.68	Hy	60—0	25
																Y 200	65	15
"	"	6^{30} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
"	"	6^{35} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
																Y 200	65	30
174	$^{11}/_{8}$ 10	11^{50} a. m.	40°54′	28°53′	120	cl.	Clear	SW	1	SW	1	"	"	"	"	N 30	Surf.	10
"	"	12^{00} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	1^{00} p. m.	"	"	"	"	"	"	"	"	"	31°0	23°8	12.0	21.7	Hy	50—0	30
"	"	1^{30} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	D 1	250	15
175	$^{11}/_{8}$ 10	7^{30} p. m.	40°48′	27°59′	1103	cl.	Clear	WNW	3	WNW	3	"	"	"	"	D 1	1200	120
"	"	7^{30} p. m.	"	"	"	"	"	"	"	"	"	26°0	24°9	12.01	21.71	Hy	1050—0	90
																Y 200	10	15
"	"	9^{45} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
"	"	9^{50} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
																Y 200	35	15
"	"	10^{15} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	30	15
"	"	10^{45} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	100	15
																Y 200	400	30
"	"	11^{20} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	350	30
																Y 200	1200	30
"	$^{12}/_{8}$ 10	0^{25} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	1150	30
176	$^{12}/_{8}$ 10	4^{00} a. m.	40°45′	27°43′	> 500	"	Clear	WNW	3	WNW	3	28°5	24°2	12.04	21.76	Y 200	65	30
"	"	4^{10} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
																P 100	Surf.	10
177	"	8^{35} a. m.	40°32′	27°03′	55	cl.	Clear	NE	5	NE	4	27°0	25°0	12.25	22.14	Hy	50—0	30
178	$^{12}/_{8}$ 10	0^{20} p. m.	40°16′	26°32′	ca. 70	"	Clear	NE	5	NE	4	"	"	"	"	Y 200	65	15
																N 30	Surf.	10
"	"	0^{25} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	0^{40} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	10	15
"	"	1^{10} p. m.	"	"	"	"	"	"	"	"	"	27°0	25°2	"	22.2	Hy	70—0	45

Station Nr.	Date	Hour	Position Lat. N.	Position Long. E.	Depth Meters	Nature of bottom	Weather	Wind Direction 0—12	Wind Force 0—12	Sea Direction 0—12	Sea Force 0—12	Temperature Air	Temperature Surface	Surface Cl ‰	Surface S ‰	Gear	Wire out Meters	Duration of haul in minutes
Mediterranean (Eastern Basin).																		
179	13/8 10	2^{15} a. m.	40°02′	25°55′	85	cl.	Cloudy	NNE	4	NNE	2	24°0	23°9	15.70	28.37	Y 200	65	30
"	"	2^{25} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
180	13/8 10	11^{00} a. m.	39°04′	25°21′	> 350	"	Cloudy	NNE	5	NNE	4	29°5	24°3	21.39	38.64	P 100	Surf.	10
181	13/8 10	1^{25} p. m.	38°49′	25°09′	255	cl.	Cloudy	NE	5	NE	5	"	"	"	"	P 30	Surf.	"
"	"	1^{30} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y	300	20
"	"	1^{50} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 50	Surf.	5
"	"	2^{55} p. m.	"	"	"	"	"	"	"	"	"	24°7	24°55	21.05	38.03	P 100	Surf.	10
182	14/8 10	8^{00} p. m.	38°13′	24°48′	500	m.	Cloudy	N	6	N	4	"	"	"	"	Hy	240—0	60
"	"	8^{15} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	65	15
"	"	10^{30} p. m.	"	"	"	"	"	"	"	"	"	24°8	25°5	20.28	36.64	D 1	650	120
"	"	10^{35} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Hy	490—0	105
"	"	11^{00} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	65	15
"	"	11^{40} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
183	16/8 10	3^{45} p. m.	37°52′	23°09′	233	m.	Clear	SSE	3	SSE	1	26°0	25°8	21.11	38.13	P 100	Surf.	10
"	"	4^{45} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	10	15
"	"	5^{10} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	600	30
"	"	5^{15} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	545	30
184	16/8 10	10^{10} p. m.	38°10′	22°33′	842	m.	Clear	NE	1	SE	2	"	"	"	"	Hy	225—0	45
"	"	10^{20} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	15
"	17/8 10	0^{45} a. m.	"	"	"	"	"	"	"	"	"	25°2	23°9	21.12	38.15	Y 200	65	15
"	"	1^{50} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
"	"	2^{15} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	2^{20} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	1000	30
"	"	2^{45} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	945	30
"	"	2^{45} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	15
185	17/8 10	11^{05} a. m.	38°12′	21°17′	> 50	"	Clear	W	1	W	1	27°0	23°95	21.19	38.28	N 30	Surf.	10
"	"	11^{10} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
186	17/8 10	8^{15} p. m.	37°57′	19°51′	> 3000	"	Clear	NW	2	NW	2	"	"	"	"	Y 200	300	15
"	"	8^{15} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	245	15
"	"	8^{45} p. m.	"	"	"	"	"	"	"	"	"	24°3	24°0	21.15	38.21	Hy	1500—0	165
"	"	11^{30} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	10	15
"	"	11^{35} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
"	"	12^{00} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	18/8 10	0^{45} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	65	15
187	18/8 10	0^{55} p. m.	37°54′	18°02′	> 2500	"	Clear	N	2	N	2	"	"	"	"	Y 200	1200	30
"	"	1^{00} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	1145	30
"	"	2^{00} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	15
"	"	4^{30} p. m.	"	"	"	"	"	"	"	"	"	26°0	25°05	21.26	38.40	N 30	Surf.	10
"	"	4^{45} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	5^{15} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Hy	1000—0	90
"	"	6^{40} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 50	25—0	"
"	"	7^{45} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 50	100—25	"
"	"	7^{50} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 50	125-100	"
188	19/8 10	4^{00} a. m.	37°51′	16°44′	ca. 2000	"	Clear	N	1	N	2	24°5	25°27	21.26	38.40	Y 200	1000	30
189	19/8 10	8^{55} a. m.	37°44′	15°58′	< 2000	"	Clear	0	"	0	"	"	"	"	"	N 30	945	30
"	"	9^{00} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	15
"	"	9^{30} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
"	"	10^{15} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	2^{40} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	1000	30
190	19/8 10	8^{00} p. m.	37°51′	15°19′	360	"	Clear	NNE	2	NNE	2	26°1	25°9	21.20	38.30	Hy	2000—0	240
"	"	8^{15} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	15
"	"	8^{20} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	L	"	1200
191	20/8 10	a. m.	Taormina Bay		"	"	"	NNE	6	NNE	1	24°0	21°93	21.04	38.01	Y 200	25	15
"	"	"	37°50′	15°18′	24	s.	Clear	"	"	"	"	"	"	"	"	N 30	Surf.	10
"	"	"	"	"	11	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	"	"	"	6	"	"	"	"	"	"	"	"	"	"	H	"	"
												28°0	21°1	21.08	38.08	D 1	"	"
												"	"	"	"	D 1	"	"
												"	"	"	"	D 1	"	"

Station Nr.	Date	Hour	Position Lat. N.	Position Long. E.	Depth Meters	Nature of bottom	Weather	Wind Direction 0—12	Wind Force 0—12	Sea Direction 0—12	Sea Force 0—12	Temperature Air	Temperature Surface	Surface Cl ‰	Surface S ‰	Gear	Wire out Meters	Duration of haul in minutes
192	20/8 10	8¹⁵ p. m.	38°07′	15°35′	652	m.	Clear	NNE	4	NNE	2	23°9	23°5	21.20	38.30	Hy	625—0	75
"	"	9⁴⁰ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	15
"	"	10¹⁰ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	15
"	"	10¹⁵ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
																Y 200	600	30
"	"	10⁵⁰ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	545	30
							Mediterranean (Western Basin).											
193	21/8 10	0⁵⁰ a. m.	38°15′	15°39′	> 100	"	Clear	N	1	0	0	23°0	25°0	21.04	38.01	Y 200	10	30
194	21/8 10	4³⁰ a. m.	38°33′	15°29′	1140	cl.	Cloudy	0	0	0	0					Y 200	10	15
												"	"	"	"	N 30	Surf.	10
"	"	4³⁵ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	5⁰⁰ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	15
																Y 200	1200	30
"	"	6⁰⁰ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	1145	30
"	"	7⁰⁰ a. m.	"	"	"	"	"	"	"	"	"	24°1	25°4	20.99	37.92	Hy	1000—0	105
195	21/8 10	2⁰⁰ p. m.	39°02′	14°55′	ca. 3160	"	Clear	0	0	0	0	27°0	26°0	21.05	38.03	Hy	2000—0	240
																Y 200	300	30
"	"	6¹⁰ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
"	"	6¹⁵ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	6⁵⁰ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	65	15
																Y 200	25	30
196	22/8 10	2⁴⁰ a. m.	39°59′	14°31′	> 600	"	Cloudy	0	0	0	0	23°5	25°25	21.07	38.06	N 30	Surf.	10
"	"	2⁴⁵ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
																Y 200	300	30
197	24/8 10	7⁰⁰ p. m.	40°34′	13°36′	> 1000	"	Cloudy	NW	3	W	4	"	"	"	"	N 30	Surf.	10
"	"	7¹⁰ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	7⁴⁵ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	15
"	"	8⁰⁰ p. m.	"	"	"	"	"	"	"	"	"	23°4	23°9	21.01	37.95	Hy	1000—0	105
198	25/8 10	7⁰⁰ a. m.	40°08′	12°26′	> 3600	"	Cloudy	NNW	5	NNW	5	23°5	24°2	21.07	38.06	P 30	Surf.	"
199	25/8 10	6³⁰ p. m.	39°32′	10°49′	ca. 2700	"	Clear	W	2	NW	2	24°0	24°9	21.17	38.24	Hy	1000—0	105
"	"	8¹⁰ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 50	200—80	"
"	"	8³⁰ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 50	80—30	"
"	"	8⁴⁵ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 50	30—0	"
"	"	9⁰⁰ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	15
"	"	9²⁵ p. m.	"	"	"	"	"	"	"	"	"	"	"			Y 200	300	20
"	"	9³⁰ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
																Y 200	1000	30
"	"	10¹⁰ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	945	30
																Y 200	25	30
200	26/8 10	3⁴⁵ a. m.	39°18′	10°11′	> 2000	"	Misty	0	0	SW	1	24°0	24°05	21.15	38.21	N 30	Surf.	10
"	"	3⁵⁰ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
201	26/8 10	8³⁰ a. m.	Piras Bay, Sardinia		16—9	s.	Clear	S	1	0	0	"	"	"	"	D 1	"	240
"	"	9⁰⁰ a. m.	39°10′	9°35′	2—0	st.	"	"	"	"	"	"	"	"	"	H	"	180
202	26/8 10	3³⁰ p. m.	38°59′	9°25′	760	m.	Clear	SSW	2	SSW	2	24°4	24°5	21.15	38.21	Hy	750—0	90
																Y 200	300	15
"	"	5⁰⁵ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
"	"	5¹⁰ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
203	27/8 10	2¹⁰ a. m.	38°52′	8°11′	> 400	"	Clear	0	0	0	0	23°0	23°6	21.14	38.19	P 30	Surf.	"
204	27/8 10	4⁰⁰ a. m.	38°52′	7°43′	> 1000	"	Clear	E	1	0	0	"	"	"	"	Y 200	25	15
																Y 200	65	15
"	"	4³⁰ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
"	"	4³⁵ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	5⁰⁰ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	30
																Y 200	1000	30
"	"	5⁴⁵ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	945	30
"	"	6⁴⁵ a. m.	"	"	"	"	"	"	"	"	"	23°6	23°5	21.14	38.19	Hy	1000—0	105
205	27/8 10	7³⁵ p. m.	39°16′	5°52′	ca. 2860	"	Clear	NNE	1	NNE	1	23°0	24°39			Y 200	25	15
"	"	7⁴⁰ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
206	28/8 10	0³⁰ a. m.	39°32′	5°15′	ca. 2860	"	Clear	0	0	NE	2	"	"	"	"	P 100	Surf.	10
"	"	1⁰⁵ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	15
"	"	1¹⁰ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	15
"	"	1⁴⁰ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
"	"	1⁴⁰ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	3⁰⁵ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	1000	45
"	"	3⁰⁵ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	945	45
"	"	4⁴⁵ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	2000	45
"	"	9³⁰ a. m.	"	"	"	"	"	"	"	"	"	23°4	24°9	20.70	37.39	N 30	1945	45
																Hy	2500—0	285
"	"		"	"	"	"	"	"	"	"	"	"	"	"	"	N 50	80—0	"

Station Nr.	Date	Hour	Position Lat. N.	Position Long.	Depth Meters	Nature of bottom	Weather	Wind Direction 0—12	Wind Force 0—12	Sea Direction 0—12	Sea Force 0—12	Temperature Air	Temperature Surface	Surface Cl ‰	Surface S ‰	Gear	Wire out Meters	Duration of haul in minutes
				E.														
206	28/8 10	10[00] a. m.	39°32′	5°15′	ca.2860	m.	Clear	0	"	NE	2	23°4	24°9	20.70	37.39	N 50	200—80	"
"	"	11[00] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 50	1000-200	"
207	28/8 10	8[50] p. m.	39°58′	3°41′	64	sh.	Cloudy	S	3	S	3	"	"	"	"	Y 200	25	15
																N 30	Surf.	10
"	"	8[55] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	9[20] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	65	15
"	"	9[50] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	D 1	100	30
"	"	9[55] p. m.	"	"	51	"	"	"	"	"	"	24°6	24°95	20.91	37.77	Hy	50—0	30
208	29/8 10	1[40] a. m.	40°18′	3°20′	>1600	"	Clear	S	3	S	3	24°3	24°0	21.12	38.15	Y 200	25	15
																N 30	Surf.	10
"	"	1[45] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
209	29/8 10	4[55] a. m.	40°34′	3°03′	>2000	"	Clear	NE	2	NE	1	"	"	"	"	Y 200	25	15
																N 30	Surf.	10
"	"	5[00] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	5[25] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	15
"	"	6[00] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	1000	15
"	"	6[00] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	945	45
"	"	7[25] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	2000	45
"	"	7[25] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	1945	45
"	"	9[30] a. m.	"	"	"	"	Cloudy	"	"	"	"	"	"	"	"	D 1	2800	180
"	"	9[30] a. m.	"	"	"	"	"	"	"	"	"	25°2	24°5	21.09	38.10	Hy	1500—0	150
"	"	1[30] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 50	30—0	"
"	"	1[45] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 50	80—33	"
"	"	2[00] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 50	200—85	"
"	"	3[00] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 50	1000-200	"
"	"	3[45] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	100	20
"	"	4[25] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	C 200	150	20
"	"	5[10] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	C 200	75—35	"
"	"	5[35] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	C 200	35—0	"
210	30/8 10	0[20] a. m.	41°10′	2°23′	780	m.	Cloudy	E	4	E	4	25°5	24°0	20.98	37.90	Hy	750—0	150
																Y 200	25	30
"	"	2[45] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
"	"	2[50] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	3[35] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	600	30
211	30/8 10	5[20] a. m.	41°17′	2°13′	150	m.	Cloudy	E	4	E	4	23°0	24°0	"	"	Y 200	25	60
																N 30	Surf.	10
"	"	5[30] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
212	30/8 10	11[55] p. m.	40°33′	1°18′	>150	"	Cloudy	ESE	1	ESE	3	23°5	24°7	20.96	37.86	P 30	Surf.	"
213	31/8 10	3[25] a. m.	40°14′	0°54′	75	m.	Cloudy	NW	3	NW	3	23°0	27°6	"	"	Y 200	25	15
																N 30	Surf.	10
"	"	3[30] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	3[50] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	95	15
"	"	4[25] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	D 1	200	15
"	"	5[00] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	M	250	30
214	31/8 10	11[45] a. m.	39°39′	0°39′	165	s. sh.	Clear	E	3	E	4	"	"	"	"	D 1	350	60
"	"	0[00] a. m.	"	"	540	m.	"	"	"	"	"	24°50	24°55	20.92	37.79	Hy	150—0	30
"	"	2[00] p. m.	"	"	500	"	"	"	"	"	"	"	"	"	"	M	1500	20
215	31/8 10	7[00] p. m.	39°14′	0°52′	>1050	"	Clear	E	1	NE	3	23°4	25°02	20.79	37.56	Hy	1000—0	135
																Y 200	25	30
"	"	9[20] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
"	"	9[30] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
216	1/9 10	5[10] a. m.	38°31′	1°24′	>85	"	Clear	0	"	E	3	23°0	25°0	20.66	37.32	Y 200	25	30
																N 30	Surf.	10
"	"	5[20] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
217	1/9 10	10[45] a. m.	38°01′	1°48′	>2000	m.	Cloudy	0	"	SE	2	23°4	24°8	20.42	36.89	Hy	2000—0	165
																Y 200	300	15
"	"	1[40] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
"	"	1[45] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
218	2/9 10	2[00] a. m.	36°54′	2°57′	ca.2000	"	Clear	ENE	3	ENE	4	"	"	"	"	Y 200	25	30
																N 30	Surf.	10
"	"	2[10] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	2[45] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	30
"	"	3[45] a. m.	"	"	"	"	"	"	"	"	"	22°0	23°5	20.34	36.74	Hy	950—0	135
219	3/9 10	7[45] p. m.	36°40′	1°49′	>280	"	Clear	E	6	ENE	6	23°5	23°7	20.35	36.76	P 30	Surf.	"
220	4/9 10	2[15] a. m.	36°25′	0°42′	>350	"	Clear	E	5	E	5	20°2	18°8	20.24	36.56	Y 200	25	30
																N 30	Surf.	10
"	"	2[20] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
				W.														
221	4/9 10	4[00] p. m.	35°44′	0°53′	37—15	st.	Clear	ENE	3	NE	4	"	"	"	"	D 2	"	"
"	"	6[35] p. m.	"	"	30	"	"	"	"	"	"	23°5	23°1	20.26	36.60	Y 200	25	15
																N 30	Surf.	10

Station Nr.	Date	Hour	Position Lat. N.	Position Long. W.	Depth Meters	Nature of bottom	Weather	Wind Direction 0—12	Wind Force 0—12	Sea Direction 0—12	Sea Force 0—12	Temperature Air	Temperature Surface	Surface Cl ‰	Surface S ‰	Gear	Wire out Meters	Duration of haul in minutes
221	4/9 10	6⁴⁰ p. m.	35°44′	0°53′	30	st.	Clear	ENE	3	NE	4	23°5	23°1	20.26	36.60	P 100	Surf.	10
222	4/9 10	8¹⁵ p. m.	35°53′	0°57′	ca. 2000	"	Clear	NNE	2	NE	4	22°8	22°88	20.28	36.64	Hy	800—0	150
"	"	10⁵⁰ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	15
"	"	11²⁰ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	30
"	"	11²⁵ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
223	5/9 10	4³⁵ a. m.	36°13′	1°28′	>2000	"	Cloudy	NNE	2	NE	4	"	"	"	"	P 100	Surf.	10
"	"	4⁴⁰ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	15
"	"	4⁵⁸ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
"	"	5⁵⁰ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	7¹⁵ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	30
"	"	10³⁵ a. m.	"	"	"	"	"	"	"	"	"	22°8	22°9	20.24	36.56	Y 200	2000	30
224	5/9 10	5⁰⁰ p. m.	36°33′	2°00′	> 950	"	Overcast	E	1	E	3	24°0	23°7	20.28	36.64	Hy	2000—0	165
"	"	7²⁰ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	2000	30
"	"	7²⁵ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Hy	950—0	120
"	"	7⁵⁰ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	15
225	6/9 10	3⁸⁰ a. m.	36°35′	3°00′	200	"	Cloudy	0	"	0	"	22°0	22°6	"	"	N 30	Surf.	10
"	"	3⁸⁵ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
226	6/9 10	3⁰⁰ p. m.	Malaga Roads		23	m.	Cloudy	SW	2	SW	1	26°0	24°0	"	"	D 1	"	"
227	6/9 10	5⁸⁵ p. m.	36°33′	4°25′	99	cl. sh.	Cloudy	SW	2	SW	1	25°0	23°6	"	"	Y 200	25	30
"	"	5⁴⁰ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
228	7/9 10	0⁶⁰ a. m.	36°02′	5°06′	> 800	"	Cloudy	W	2	W	2	"	"	"	"	P 100	Surf.	10
"	"	1⁵⁵ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	1200	30
"	"	2⁰⁰ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	1145	30
"	"	2⁴⁰ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	30
"	"	3⁴⁵ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
"	"	4⁰⁰ a. m.	"	"	720	cl.	"	"	"	"	"	19°4	18°42	20.18	36.45	P 100	Surf.	10
																Y 200	25	30
																D 1	1600	150
																Hy	700—0	120

Atlantic and Channel.

229	8/9 10	4⁵⁵ a. m.	35°51′	5°58′	"	"	Overcast	SSW	2	SW	2	"	"	"	"	Y 200	25	30
"	"	5⁰⁰ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	5⁴⁰ a. m.	"	"	343	cl.	"	"	"	"	"	"	"	"	"	Y 200	300	30
"	"	8²⁰ a. m.	"	"	485	"	Cloudy	SW	3	"	"	20°2	21°45	20.16	36.42	Hy	475—0	100
"	"	10⁰⁵ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 50	Surf	10
230	8/9 10	11¹⁰ a. m.	35°57′	6°00′	290	st.	Cloudy	WSW	3	WSW	3	21°0	21°0	20.09	36.29	N 50	Surf.	10
231	8/9 10	9¹⁵ p. m.	35°56′	7°16′	> 950	"	Cloudy	NNW	2	NW	3	"	"	"	"	Hy	275 -0	60
"	"	10⁰⁰ p. m.	"	"	"	"	"	"	"	"	"	20°04	21°30	20.16	36.42	D 1	1600	120
"	9/9 10	0¹⁵ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Hy	950—0	90
"	"	0²⁰ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	30
"	"	1¹⁵ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 30	Surf.	10
"	"	2¹⁵ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	3²⁰ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	30
"	"	4⁰⁵ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	1200	30
232	9/9 10	7⁰⁰ p. m.	36°28′	9°06′	ca. 3500	"	Cloudy	NNW	2	NNW	3	20°7	22°5	20.25	36.58	N 30	1145	30
"	"	8⁵⁰ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	30
"	"	9⁰⁰ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	30
"	"	9³⁵ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Hy	950—0	105
"	"	10³⁵ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	30
"	"	11⁴⁵ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 50	Surf.	10
233	10/9 10	5⁰⁵ a. m.	36°49′	9°15′	658	"	Cloudy	NNW	2	NNW	3	19°5	19°1	19.91	35.97	P 100	Surf.	10
"	"	5¹⁰ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	30
234	10/9 10	5¹⁵ p. m.	38°10′	9°20′	910	cl.	Cloudy	N	2	NNW	2	"	"	"	"	Y 200	1000	30
"	"	5³⁰ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	2000	30
"	"	7³⁰ p. m.	"	"	"	"	"	"	"	"	"	20°0	19°3	19.88	35.91	Hy	875—0	90
"	"	7⁴⁵ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 50	25—0	105
"	"	8²⁰ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 50	100—25	"
"	"	9⁰⁰ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 50	200—95	"
"	"	9⁴⁵ p. m.	"	"	"	"	Clear	N	1	N	2	"	"	"	"	N 50	700-200	"
																Y 200	25	30

Station Nr.	Date	Hour	Position Lat. N.	Position Long.	Depth Meters	Nature of bottom	Weather	Wind Direction 0—12	Wind Force 0—12	Sea Direction 0—12	Sea Force 0—12	Temperature Air	Temperature Surface	Surface Cl ‰	Surface S ‰	Gear	Wire out Meters	Duration of haul in minutes
				W														
234	10/9 10	9[50] p. m.	38°10′	9°20′	910	cl.	Cloudy	N	1	N	2	20°0	19°30	19.88	35.91	P 100	Surf.	10
																N 50	Surf.	10
"	"	10[30] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	30
"	"	11[20] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	1000	30
235	11/9 10	5[00] a. m.	38°38′	9°25′	110	m.	Clear	ENE	1	N	3	19°5	18°02	19.90	35.95	Y 200	25	30
																N 50	Surf.	10
"	"	5[05] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
236	13/9 10	11[00] p. m.	39°56′	9°26′	> 100	"	Misty	0	0	N	3	18°5	19°04	19.72	35.62	Y 200	25	30
																N 50	Surf.	10
"	"	11[00] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
237	14/9 10	7[30] a. m.	40°54′	9°28′	> 1300	"	Misty	N	2	N	4	18°0	19°12	19.77	35.71	P 30	Surf.	"
238	14/9 10	5[40] p. m.	41°56′	9°30′	> 1700	"	Clear	NNE	7	NNE	7	20°5	19°38	19.80	35.77	P 30	Surf.	"
239	15/9 10	5[10] a. m.	43°02′	9°25′	> 100	"	Clear	NNE	3	NNE	4	17°5	14°4	19.74	35.66	Y 200	25	30
																N 50	Surf.	10
"	"	5[15] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
240	15/9 10	8[30] p. m.	44°34′	8°16′	> 4000	"	Cloudy	ENE	4	N	5	16°5	17°34	19.69	35.57	Y 200	25	15
"	"	9[00] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	300	15
"	"	9[05] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	N 50	Surf.	10
"	"	9[40] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
241	16/9 10	7[10] a. m.	45°26′	7°33′	> 4000	"	Cloudy	E	5	N	5	17°0	17°73	19.68	35 55	Y 200	1000	30
242	16/9 10	4[10] p. m.	46°19′	6°48′	> 4000	"	Cloudy	E	4	N	4	16°8	17°34	19.69	35.57	P 30	Surf.	"
"	"	7[00] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Hy	950—0	90
"	"	10[20] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	C 200	4350	60
"	"	10[25] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	65	15
																P 100	Surf.	10
"	"	10[55] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 30	Surf.	10
"	"	10[55] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	65	30
243	17/9 20	4[00] a. m.	46°43′	6°28′	> 4270	"	Cloudy	E	4	N	5	16°5	17°2	19.60	35.41	Y 200	65	30
																P 30	Surf.	10
"	"	4[00] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
244	17/9 10	9[20] a. m.	47°08′	6°08′	> 900	"	Overcast	E	5	NW, SE	4, 5	17°0	16°84	19.65	35.50	Hy	940—0	40
																Y 200	1000	30
"	"	9[55] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 30	Surf.	"
"	"	10[30] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
245	17/9 10	4[20] p. m.	47°14′	6°02′	182, 330	crl., sh.	Misty	E	3	N	5	17°5	16°52	"	"	Y	250	30
																P 30	Surf.	10
"	"	4[25] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
"	"	5[15] p. m.	"	"	330, > 460	st.	"	"	"	"	"	"	"	"	"	Y 200	400	120
"	"	7[30] p. m.	"	"	> 460	"	"	"	"	"	"	"	"	"	"	Y 200	65	30
"	"	8[15] p. m.	"	"	"	"	"	ENE	2	SE	4	"	"	"	"	Y 200	65	30
"	"	8[55] p. m.	"	"	> 460	"	"	"	"	"	"	"	"	"	"	Y 200	150	15
"	"	9[55] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	65	15
246	18/9 10	8[15] a. m.	48°02′	5°23′	90	st.	Misty	E	3	NE	3	16°5	14°6	19.52	35.26	Y 200	100	15
																P 30	Surf.	10
"	"	8[20] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
247	19/9 10	8[35] p. m.	48°43′	4°45′	> 100	"	Misty	N	3	N	2	14°5	12°8	19.51	35.25	Y 200	65	15
																P 30	Surf.	10
"	"	8[40] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
248	20/9 10	9[25] p. m.	49°52′	2°20′	> 100	"	Cloudy	NE	5	NE	5	12°5	15°12	19.33	34.92	Y 200	65	15
																P 30	Surf.	10
"	"	9[30] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
				E														
249	21/9 10	11[50] p. m.	51°08′	1°15′	> 50	"	Squally	NE	3	NE	3	12°5	15°30	"	"	Y 200	65	15
																P 30	Surf.	10
"	"	11[55] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10

2. Stations of the "Thor" in the Atlantic S. of Ireland 1905 and 1906.

1905.

				W														
79.05	13/6 05	6[40] a. m.	53°06′	10°42′	130	f. s.	Misty	ENE	3	ENE	3	14°5	13°36	19.56	35.34	Y 200	65	30
"	"	6[45] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	7[15] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	30
80.05	13/6 05	2[45] p. m.	52°06′	11°10′	143	s. g.	Misty	N	2	N	2	17°5	14°11	19.66	35.52	Y 200	65	30
"	"	2[50] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	3[25] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	30
81.05	13/6 05	10[15] p. m.	51°32′	12°03′	980, 1040	f. s.	Misty	E	1	SW	Swell	16°0	13°8	19.66	35.52	Y 200	300	60
"	"	10[20] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	11[45] p. m.	"	"	1040, 1090	"	Cloudy	E	4	"	"	"	"	"	"	Y 330	300	120

Station Nr.	Date	Hour	Position Lat. N.	Position Long. W.	Depth Meters	Nature of bottom	Weather	Wind Direction 0—12	Wind Force 0—12	Sea Direction 0—12	Sea Force 0—12	Temperature Air	Temperature Surface	Surface Cl ‰	Surface S ‰	Gear	Wire out Meters	Duration of haul in minutes
81.05	14/6 05	2[20] a. m.	51°32′	12°03′	1090, 1330	f. s.	Cloudy	SSW	4	SW	5	16°3	13°8	19.66	35.52	Y 330	200	120
"	"	5[00] a. m.	"	"	1330, 960	"	"	S	4	"	"	"	"	"	"	Y 330	300	120
"	"	7[35] a. m.	"	"	960, 1420	"	"	"	"	"	"	"	"	"	"	Y 330	300	120
"	"	10[15] a. m.	"	"	1420, 1290	"	"	S	5	"	"	"	"	"	"	Y 330	300	120
"	"	1[00] p. m.	"	"	1290, 1060	"	"	S	6	"	"	"	"	"	"	Y 330	300	120
82.05	14/6 05	11[00] p. m.	51°00′	11°43′	1340	m. s.	Squally	SE by E	7	SE by E	6	15°5	13°79	19.63	35.46	Y 330	300	120
"	15/6 05	1[35] a. m.	"	"	1020, 1370	oz.	Cloudy	S by E	4	SE	6	"	"	"	"	Y 330	300	120
"	"	4[15] a. m.	"	"	1370, 1220	"	"	"	"	"	"	"	"	"	"	Y 330	300	210
"	"	8[20] a. m.	"	"	1210	"	"	"	"	"	"	"	"	"	"	Y 330	600	120
"	"	0[45] p. m.	"	"	1350, 840	"	"	"	"	"	"	"	"	"	"	Y 330	1200	120
"	"	3[45] p. m.	"	"	840, 1400	"	"	"	"	"	"	"	"	"	"	Y 330	800	120
"	"	6[40] p. m.	"	"	1400	"	Rain	SE	6	"	"	13°5	13°98	19.63	35.46	Y 330	200	60
83.05	16/6 05	3[20] a. m.	51°13′	10°30′	146	f. s.	Cloudy	SSW	6	SSW	7	"	"	"	"	Y 200	65	30
"	"	3[25] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	3[55] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	30
84.05	18/6 05	8[10] p. m.	51°24′	8°18′	95	s. sh.	Cloudy	S by E	5	S by E	5	14°1	14°25	19.50	35.23	Y 200	65	30
"	"	8[15] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	8[45] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	30
85.05	19/6 05	7[45] a. m.	50°19′	8°30′	120	cl. s.	Squally	S by W	7	S by W	7	14°7	14°22	19.58	35.37	Y 200	65	30
"	"	8[00] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	8[20] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	30
86.05	19/6 05	7[40] p. m.	49°14′	8°45′	95	f. s.	Rain	SSW	8	SW	8	14°0	14°05	19.59	35.39	Y 200	65	30
"	"	7[50] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	8[35] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	150	30
"	"	9[10] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	65	30
87.05	20/6 05	3[15] p. m.	48°05′	8°29′	2000	"	Squally	SSW	7	SSW	8	"	"	"	"	Y 200	300	120
88.05	20/6 05	8[45] p. m.	48°09′	8°30′	600, 995	f. y. s.	Squally	SSW	7	SW	8	"	"	"	"	Y 200	300	120
"	"	11[45] p. m.	"	"	995, 608	"	Rain	"	"	SW	9	"	"	"	"	Y 200	300	240
89.05	21/6 05	0[45] p. m.	47°33′	7°40′	500, 300	f. s.	Clear	SSW	2	SW	5	20°0	"	"	"	Y 330	300	60
90.05	21/6 05	3[55] p. m.	47°47′	8°00	885, 1012	m. s.	Clear	Calm	"	SW	5	16°5	14°40	19.67	35.53	Y 330	300	120
"	"	7[30] p. m.	"	"	1012, 830	"	"	"	"	"	"	"	"	"	"	Y 330	500	120
"	"	11[45] p. m.	"	"	1800, 1600	oz.	Foggy	ENE	3	SW	4	"	"	"	"	Y 330	300	120
"	22/6 05	2[15] a. m.	"	"	1600, 740	"	"	"	"	"	"	"	"	"	"	Y 330	300	120
91.05	22/6 05	4[30] p. m.	17°13′	6°12′	1500, 903	m. s.	Clear	ENE	3	ENE	2	16°0	14°07	19.71	35.61	Y 330	500	120
"	"	7[00] p. m.	"	"	903	"	"	"	"	"	"	"	"	"	"	Y 330	300	60
92.05	24/6 05	5[45] a. m.	48°55′	12°20′	1450, 1360	cl. s.	Clear	E	1	W	4	19°5	15°04	"	"	Y 330	300	60
"	"	5[50] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	7[30] a. m.	"	"	1360, 1432	"	"	"	"	"	"	"	"	"	"	Y 330	500	60
"	"	9[30] a. m.	"	"	1432, 1310	"	"	"	"	"	"	"	"	"	"	Y 330	200	60
93.05	24/6 05	3[30] p. m.	49°25′	12°20′	1280, 1310	cl. s.	Clear	ESE	4	W	4	"	"	"	"	Y 330	300	60
"	"	3[40] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	5[00] p. m.	"	"	1310, 1350	"	"	"	"	"	"	"	"	"	"	Y 330	300	120
"	"	7[45] p. m.	"	"	1350, 1230	"	"	"	"	"	"	16°2	14°61	19.63	35.47	Y 330	300	120
"	"	10[30] p. m.	"	"	1230, 1270	"	"	ESE	5	"	"	"	"	"	"	Y 330	300	120
"	25/6 05	1[15] a. m.	"	"	1270, 1310	"	"	ESE	6	"	"	"	"	"	"	Y 330	200	120
"	"	4[00] a. m.	"	"	1310, 1330	"	"	"	"	"	"	"	"	"	"	Y 330	250	120
"	"	7[45] a. m.	"	"	1330, 1440	"	"	SE	6	SE	6	"	"	"	"	R. T	2700	120
"	"	12[00] a. m.	"	"	1440, 1530	"	"	SE	2	SE	4	"	"	"	"	R. T	3000	120
"	"	4[45] p. m.	"	"	1275, 1180	"	"	SE	3	SE	3	15°1	15°10	19.66	35.52	O	2700	120
"	26/6 05	1[00] a. m.	"	"	1180, 1280	"	"	"	"	"	"	"	"	"	"	Y 330	100	60
94.05	27/6 05	5[45] a. m.	50°02′	6°20′	86	s. g.	Clear	Calm	"	0	"	17°4	14°74	19.52	35.26	Y 330	65	30
"	"	5[50] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	6[25] a. m.	"	"	"	"	Misty	W	1	W	1	"	"	"	"	Y 330	25	30
95.05	27/6 05	1[55] p. m.	49°56′	5°08′	74	st.	Cloudy	NW	1	NW	1	19°0	15°90	"	"	Y 330	65	30
"	"	2[00] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	2[40] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	90	30
"	"	3[15] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	30
96.05	27/6 05	7[45] p. m.	50°15′	4°19′	50	f. s.	Cloudy	NW	4	NW	4	16°0	15°10	19.49	35.21	Y 200	65	30
"	"	7[50] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	8[20] p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	30
97.05	29/6 05	3[35] a. m.	50°17′	3°14′	60	f. s.	Overcast	SE	5	SE	4	14°0	14°82	"	"	Y 200	75	30
"	"	3[40] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	4[10] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	30
							1906.											
2706	1/6 06	3[00] a. m.	50°00′	2°25′	69	st.	Cloudy	NNW	4	NW	4	7°5	8°45	19.45	35.14	Y 200	10	60
"	"	3[10] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	4[05] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	30	60
"	"	5[10] a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	75	60

Station Nr.	Date	Hour	Position Lat. N.	Position Long. W.	Depth Meters	Nature of bottom	Weather	Wind Direction	Wind Force 0–12	Sea Direction	Sea Force 0–12	Temperature Air	Temperature Surface	Surface Cl ‰	Surface S ‰	Gear	Wire out Meters	Duration of haul in minutes
27.06	1/5 06	6²⁰ a. m.	50°00′	2°25′	69	st.	Cloudy	NNW	4	NW	4	7°5	8°45	19.45	35.14	G	69	1 haul
28.06	1/5 06	1⁴⁰ p. m.	50°08′	3°51′	58	g.s.	Cloudy	W	5	W	3	9°2	8°70	19.45	35.14	Y 200	10	30
"	"	1⁴⁵ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	2¹⁵ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	60	30
29.06	1/5 06	4³⁰ p. m.	50°15′	4°10′	30	g.	Cloudy	WNW	5	W	2	9°2	8°70	19.45	35.14	P 100	Surf.	5
30.06	2/5 06	5⁴⁵ a. m.	50°11′	4°18′	51	st.	Misty	SSW	4	SW	4	9°8	9°13	19.45	35.14	Y 200	10	30
"	"	5¹¹ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	6¹⁵ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	60	30
31.06	2/5 06	1⁴⁰ p. m.	49°45′	4°42′	98	s.	Misty	SE	2	W	5	14°6	9°90	19.53	35.28	Y 200	10	30
"	"	1⁴⁵ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	2¹⁵ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	50	30
"	"	2⁵⁰ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	120	30
32.06	2/5 06	10¹⁵ p. m.	48°40′	5°04′	113	s.	Rain	ENE	2	W	5	10°1	9°91	19.59	35.39	Y 200	120	30
"	"	10²⁰ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	10⁵⁰ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	50	30
"	"	11²⁵ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	10	30
33.06	3/5 06	10⁰⁰ a. m.	48°00′	4°52′	35	st.	Misty	NNE	3	W	5	16°0	10°30	19.41	35.07	Y 200	45	30
"	"	10⁰⁵ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	10³⁵ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	15	30
34.06	3/5 06	0⁰⁵ p. m.	47°55′	4°52′	50	st.	Misty	NNE	2	W	5	16°0	10°30	19.41	35.07	Y 200	60	30
35.06	3/5 06	7⁰⁵ p. m.	47°05′	4°26′	146	sh.	Clear	NNE	2	W	4	12°5	12°20	19.51	35.25	Y 200	10	30
"	"	7¹⁰ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	8¹⁰ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	60	30
"	"	8⁴⁵ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	175	30
36.06	10/5 06	2¹⁰ a. m.	44°21′	2°37′	1140	m.	Misty	W	3	W	3	"	"	"	"	Y 330	25	30
"	"	2²⁰ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	2⁵⁵ a. m.	"	"	1125	"	"	"	"	"	"	"	"	"	"	Y 330	300	120
"	"	5⁵⁵ a. m.	"	"	1125	"	"	"	"	"	"	"	"	"	"	Y 330	1250	120
"	"	9⁰⁵ a. m.	"	"	1050, 1035	m.	"	W by N	3	WNW	4	"	"	"	"	Y 330	800	120
"	"	0¹⁵ p. m.	"	"	1035, 1095	"	"	"	"	"	"	14°5	"	"	"	Y 330	300	120
37.06	10/5 06	7⁰⁵ p. m.	44°01′	2°49′	1400	m.	Cloudy	N	3	NW	4	12°6	13°13	19.70	35.59	Y 330	300	120
"	"	7¹⁵ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	9⁵⁵ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 330	200	120
38.06	11/5 06	3⁰⁰ a. m.	43°52′	2°27′	1290	m.	Cloudy	NNW	2	NW	4	"	"	"	"	Y 330	250	120
"	"	3¹⁰ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
39.06	11/5 06	9⁰⁰ a. m.	43°39′	2°07′	1420	"	Overcast	E	1	E	1	"	"	"	"	Y 300	300	120
"	"	9⁰⁵ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
40.06	11/5 06	1¹⁵ p. m.	43°23′	2°02′	110	"	Overcast	E	1	E	1	"	"	"	"	Y 330	100	30
"	"	1²⁰ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
41.06	14/5 06	6³⁰ p. m.	43°23′	2°01′	102	f. s.	Cloudy	WNW	4	W	3	15°3	15°0	19.22	34.72	Y 330	120	120
"	"	6³⁵ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	8⁴⁵ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 330	60	120
"	"	11⁰⁰ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 330	15	120
42.06	15/5 06	9²⁰ a. m.	43°31′	2°13′	348	m.	Rain	WNW	7	WNW	7	"	"	"	"	Y 200	400	60
"	"	9²⁵ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	10³⁰ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	70	60
"	"	11³⁵ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	15	60
43.06	15/5 06	2¹⁵ p. m.	43°37′	2°08′	1128	m.	Cloudy	NW	3	NW	4	14°2	14°06	19.37	34.99	Y 330	400	120
"	"	2²⁰ p. m.	"	"	1500	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	7⁵⁰ p. m.	"	"	1500, 480	"	"	"	"	"	"	"	"	"	"	Y 330	1500	120
"	16/5 06	2⁴⁵ a. m.	"	"	1650, 1030	"	"	N	3	"	"	"	"	"	"	Y 330	250	120
"	"	5²⁰ a. m.	"	"	1030, 1290	"	"	"	"	"	"	"	"	"	"	Y 330	600	120
"	"	8¹⁰ a. m.	"	"	1290, 980	"	"	"	"	"	"	"	"	"	"	Y 330	1500	120
44.06	16/5 06	4⁰⁰ p. m.	43°58′	1°27′	40	g.	Cloudy	NW	4	NW	4	15°5	15°70	17.00	30.72	Y 330	50	30
"	"	3¹⁰ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	3⁴⁵ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 330	15	30
45.06	16/5 06	7³⁵ p. m.	44°19′	1°51′	125	f. s.	Cloudy	NNW	4	NNW	5	12°2	14°88	18.92	34.18	Y 330	60	"
"	"	7⁴⁰ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
46.06	17/5 06	1⁴⁵ a. m.	44°37′	2°17′	1360	m.	Squally	NNW	6	NNW	6	"	"	"	"	Y 330	300	120
"	"	1⁵⁵ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	4³⁵ a. m.	"	"	1380, 1530	"	"	"	"	"	"	8°5	13°0	19.61	35.43	Y 330	100	120
47.06	17/5 06	2²⁵ p. m.	45°00′	2°57′	1015	"	Squally	NNW	6	NNW	6	12°5	13°04	19.36	34.97	Y 330	300	120
"	"	2³⁰ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
48.06	18/5 06	1⁵⁰ a. m.	45°43′	3°47′	"	"	Squally	NNW	6	NNW	6	8°0	12°36	"	"	Y 330	300	120
"	"	2⁰⁰ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
49.06	18/5 06	10⁴⁵ a. m.	46°13′	4°24′	1560, 590	m.	Squally	NNW	4	NNW	5	9°8	12°03	19.69	35.57	Y 330	300	120
"	"	10⁵⁰ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	1¹⁵ p. m.	"	"	590, 1140	"	"	"	"	"	"	"	"	"	"	Y 330	300	120
50.06	19/5 06	2²⁰ a. m.	46°50′	5°22′	740, >1500	m.	Cloudy	NNW	4	NNW	5	9°0	11°54	19.71	35.61	Y 330	300	120
"	"	2⁵⁰ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
51.06	20/5 06	3⁰⁰ a. m.	48°07′	9°03′	860, 1920	m. s.	Cloudy	NNE	3	NW	3	12°5	11°36	19.70	35.60	Y 330	300	120

Station Nr.	Date	Hour	Position Lat. N.	Position Long. W.	Meters Depth	Nature of bottom	Weather	Wind Direction 0—12	Wind Force 0—12	Sea Direction 0—12	Sea Force 0—12	Temperature Air	Temperature Surface	Surface Cl ‰	Surface S ‰	Gear	Wire out Meters	Duration of haul in minutes
51.06	20/5 06	3¹⁵ a. m.	48°07′	9°03′	860, 1920	m. s.	Cloudy	NNE	3	NW	3	12°5	11°36	19.70	35.60	P 100	Surf.	5
52.06	21/5 06	0²⁵ a. m.	48°43′	12°05′	1860, 1910	m.	Misty	NW	2	NW	2	10°2	11°71	19.66	35.52	Y 330	300	120
"	"	0³⁵ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	3¹⁵ a. m.	"	"	1910, 1945	"	"	"	"	"	"	"	"	"	"	Y 330	300	120
"	"	6¹⁰ a. m.	"	"	1945	"	"	"	"	"	"	"	"	"	"	Y 330	300	120
53.06	21/5 06	0⁰⁵ p. m.	48°55′	12°03′	1174, 1080	m. s.	Cloudy	SSE	4	N	5	14°5	11°70	19.67	35.53	Y 330	300	120
54.06	21/5 06	4⁵⁵ p. m.	49°13′	11°58′	940, 975	m.	Cloudy	SSE	4	N	5	12°5	11°70	"	"	Y 330	300	120
55.06	21/5 06	9⁵⁵ p. m.	49°23′	12°12′	1220, 1330	m.	Cloudy	SE	6	NE	5	9°7	11°34	19.64	35.48	Y 330	300	120
"	22/5 06	1⁰⁵ a. m.	"	"	1330	"	"	"	"	SE	7	"	"	"	"	Y 330	200	120
56.06	22/5 06	9⁵⁰ p. m.	51°24′	10°20′	130	f. s.	Squally	NE	6	S	6	8°0	10°20	19.56	35.34	Y 330	150	60
"	"	11¹⁰ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 330	25	60
57.06	23/5 06	4¹⁵ a. m.	51°58′	10°25′	75	st.	Cloudy	ENE	3	S	5	8°5	9°70	19.48	35.19	Y 330	80	60
"	"	4³⁰ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	5²⁰ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 330	25	60
59.06	30/5 06	9⁰⁵ a. m.	51°58′	10°25′	81	st.	Squally	SW	5	SW	5	10°47	10°74	"	"	Y 330	100	60
"	"	9¹⁰ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	10¹⁰ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 330	25	60
"	"	11¹⁵ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 330	60	60
"	"	0²⁵ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 330	80	60
"	"	1³⁵ p. m.	"	"	80	"	Foggy	"	"	"	"	"	"	"	"	Y 330	40	60
"	"	2⁵⁰ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 330	10	60
"	"	4⁰⁵ p. m.	"	"	84	s. sh.	"	"	"	"	"	"	"	"	"	Y 330	120	45
60.06	30/5 06	10²⁰ p. m.	51°27′	11°10′	202	s.	Rain	WSW	4	W	5	11°0	10°90	19.54	35.30	Y 330	250	60
"	"	10²⁵ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	11³⁰ p. m.	"	"	"	"	Overcast	"	"	"	"	"	"	"	"	Y 330	70	60
"	31/5 06	0⁴⁰ a. m.	"	"	198	"	Clear	NW	5	NW	4	"	"	"	"	Y 330	50	60
61.06	31/5 06	7⁴⁵ a. m.	51°04′	11°39′	1320, 1020	m.	Squally	NW	5	NW	5	"	"	"	"	Y 330	300	120
"	"	8¹⁵ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	10²⁰ a. m.	"	"	1020, 1420	"	"	"	"	"	"	"	"	"	"	Y 330	400	120
"	"	1⁰⁵ p. m.	"	"	1420, 1300	"	"	"	"	"	"	"	"	"	"	Y 330	500	120
"	"	3⁵⁰ p. m.	"	"	1300, 1450	"	"	WNW	5	NW	6	"	"	"	"	Y 330	600	120
"	"	6⁵⁰ p. m.	"	"	1450	"	Misty	"	6	"	7	11°0	11°55	"	"	Y 330	800	120
"	"	9⁴⁰ p. m.	"	"	"	"	"	"	7	"	"	"	"	"	"	Y 330	300	120
62.06	4/6 06	9⁵⁵ p. m.	50°25′	12°44′	2480	"	Cloudy	SE	4	S	5	15°0	12°00	"	"	Y 330	300	120
"	5/6 06	0¹⁵ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 330	200	120
"	"	2⁴⁵ a. m.	"	"	2775	"	"	"	"	"	"	"	"	"	"	Y 330	1500	120
63.06	5/6 06	5³⁰ p. m.	49°27′	13°22′	2140	"	Cloudy	Calm	"	S	4	14°8	13°15	19.65	35.50	Y 330	300	120
64.06	5/6 06	10³⁵ p. m.	49°17′	14°03′	"	"	Foggy	Calm	"	S	3	12°5	13°04	19.69	35.57	Y 330	300	120
"	6/6 06	2³⁰ a. m.	"	"	"	"	Misty	"	"	"	"	"	"	"	"	Y 330	200	120
65.06	6/6 06	7⁰⁰ a. m.	49°04′	14°52′	6020	"	Misty	E	1	S	2	15°5	13°35	19.65	35.51	Y 330	300	120
66.06	6/6 06	2¹⁵ p. m.	48°43′	15°17′	>4000	"	Misty	0	"	S	2	22°5	13°25	"	"	Y 330	300	60
"	"	3³⁰ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 330	400	60
"	"	5⁰⁰ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	G	1000	40
"	"	5⁵⁵ p. m.	"	"	"	"	"	"	"	"	"	13°9	13°70	19.71	35.61	Y 330	200	60
67.06	7/6 06	1⁰⁵ a. m.	48°29′	14°15′	>4000	"	Cloudy	SE	2	SE	3	"	"	"	"	Y 330	200	120
"	"	3⁵⁰ a. m.	"	"	"	"	Misty	"	"	"	"	"	"	"	"	Y 330	10	60
"	"	5⁰⁰ a. m.	"	"	"	"	"	"	"	"	"	13°5	13°30	19.68	35.55	Aa. T	1700	120
68.06	7/6 06	3⁵⁰ p. m.	48°04′	12°40′	>4000	"	Clear	E	3	E	4	13°0	13°30	19.66	35.52	Y 330	400	60
69.06	7/6 06	10⁵⁰ p. m.	47°40′	12°41′	>4000	"	Clear	E	3	E	4	12°3	13°37	19.69	35.57	Y 330	200	60
70.06	8/6 06	3⁰⁵ a. m.	47°20′	12°23′	>4000	"	Misty	E	3	E	4	12°0	13°27	19.68	35.55	Y 330	200	60
"	"	5⁰⁰ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 330	300	60
71.06	8/6 06	2⁰⁰ p. m.	48°05′	11°50′	>4000	"	Clear	NE	1	NE	1	19°8	14°59	19.69	35.58	Y 330	400	60
"	"	3¹⁵ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 330	300	60
"	"	3²⁰ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	10
72.06	8/6 06	9⁰⁰ p. m.	48°41′	11°30′	2600	"	Clear	NE	1	NE	2	13°4	13°75	19.69	35.58	Y 330	300	60
"	"	10¹⁵ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 330	200	60
73.06	9/6 06	3²⁰ a. m.	48°43′	12°05′	1340	"	Clear	NE	2	NE	2	12°7	13°25	19.69	35.57	Y 330	200	60
"	"	4⁵⁰ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Aa. T	400	60
74.06	9/6 06	10⁰⁰ a. m.	49°23′	12°13′	1170	"	Clear	NE	1	W	2	"	"	"	"	Y 330	400	60
"	"	1²⁰ p. m.	"	"	1170	"	"	"	"	"	"	"	"	"	"	Aa 2	2000	60
"	"	3³⁵ p. m.	"	"	1250	"	"	"	"	"	"	"	"	"	"	Aa 2	2400	60
"	"	6³⁰ p. m.	"	"	1250	"	"	"	"	"	"	"	"	"	"	Aa 2	2400	60
"	"	9⁵⁰ p. m.	"	"	1215	"	"	"	"	"	"	"	"	"	"	Aa 2	2500	60
"	10/6 06	0⁴⁰ a. m.	"	"	1215	"	"	"	"	"	"	"	"	"	"	Y 330	100	120
"	"	3¹⁰ a. m.	"	"	1245	"	"	"	"	"	"	"	"	"	"	Y 330	200	120
"	"	6⁰⁵ a. m.	"	"	1245, 1298	"	"	"	"	"	"	"	"	"	"	Y 330	2000	60
"	"	11³⁵ a. m.	"	"	1298	"	"	"	"	"	"	18°7	14°78	19.70	35.59	D 2	1400	30
75.06	10/6 06	4³⁰ p. m.	49°20	12°39′	1520	"	Clear	NE	3	NE	2	"	"	"	"	Aa 2	2800	90
"	"	8¹⁵ p. m.	"	"	"	"	"	"	"	"	"	15°5	14°41	"	"	Aa 2	2800	90
"	"	11²⁰ p. m.	"	"	"	"	Foggy	"	"	"	"	"	"	"	"	Aa 2	400	120
"	14/6 06	1⁵⁰ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Aa 2	800	120

Station Nr.	Date	Hour	Position Lat. N.	Position Long. W.	Depth Meters	Nature of bottom	Weather	Wind Direction 0—12	Wind Force 0—12	Sea Direction 0—12	Sea Force 0—12	Temperature Air	Temperature Surface	Surface Cl ‰	Surface S ‰	Gear	Wire out Meters	Duration of haul in minutes
75.06	11/6 06	4³⁰ a. m.	49°20′	12°39′	1520	"	Foggy	NE	3	NE	2	15°5	14°41	19.70	35.59	Aa 2	1500	120
76.06	11/6 06	3⁰⁰ p. m.	49°27′	13°33′	>2600	"	"	NE	3	NE	2	13°5	14°5	"	"	Y 200	2800	120
"	"	6¹⁵ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	800	120
"	"	9⁴⁵ p. m.	"	"	"	"	"	NE	5	NE	4	"	"	"	"	D 2	2800	30
"	12/6 06	0²⁰ a. m.	"	"	"	"	Cloudy	NE	4	"	"	"	"	"	"	Y 330	100	120
"	"	2⁴⁰ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 330	200	120
"	"	5⁰⁵ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 330	300	120
"	"	10⁹⁰ a. m.	"	"	2100	y. s.	"	"	"	"	"	13°7	13°61	"	"	D 2	2700	60
77.06	13/6 06	1⁴⁵ a. m.	50°45	11°53′	>2000	"	Overcast	NE	6	NE	6	12°3	13°06	"	"	Y 330	200	60
78.06	15/6 06	6⁴⁰ p. m.	51°35′	11°36′	475	"	Cloudy	N	6	N	6	12°5	12°84	"	"	Y 330	300	120
"	"	9⁰⁰ p. m.	"	"	"	"	"	NNE	5	NE	5	"	"	"	"	Y 330	200	60
79.06	16/6 06	1³⁰ a. m.	51°37′	11°12′	210	f. y. s.	Squally	NE	4	NE	5	13°5	13°47	19.58	35.38	Y 330	200	60
"	"	2⁵⁰ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 330	300	60
"	"	4⁰⁰ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 330	100	60
80.06	16/6 06	9³⁰ a. m.	51°34′	11°50′	1040	y. s.	Cloudy	ESE	3	NE	3	14°5	13°04	19.66	35.52	Y 330	400	120
"	"	0⁴⁰ p. m.	"	"	960	"	"	"	"	"	"	"	"	"	"	Aa 2	1900	90
"	"	3⁴⁵ p. m.	"	"	1140	"	"	"	"	"	"	"	"	"	"	Aa 2	1900	90
"	"	6³⁰ p. m.	"	"	1140	"	Clear	ENE	3	"	"	"	"	"	"	Y 200	1200	120
"	"	9⁰⁵ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 330	250	120
"	"	11³⁰ p. m.	"	"	"	"	Cloudy	NNE	3	NNE	3	"	"	"	"	Y 330	200	120
"	17/6 06	2⁰⁰ a. m.	"	"	1200	cl.	"	"	"	"	"	"	"	"	"	Y 330	100	120
82.06	18/6 06	2⁰⁰ a. m.	51°08′	13°05′	"	"	Cloudy	NNW	2	N	3	12°5	13°58	19.66	35.52	Y 330	200	120
83.06	20/6 06	10²⁰ a. m.	51°58	10°25′	81	st.	Misty	S by W	5	W	5	14°7	12°62	"	"	Y 330	100	60
"	"	11²⁵ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 330	60	60
"	"	0³⁰ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 330	25	60
"	"	1⁴⁰ p. m.	"	"	"	"	"	"	"	"	"	"	13°35	19.47	35.17	Y 330	120	60
84.06	21/6 06	1²⁰ a. m.	52°54′	9°36′	60	f. y. s.	Misty	SW	3	SW	3	"	"	"	"	Y 330	60	60
"	"	2³⁰ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 330	100	60
"	"	3⁴⁵ a. m.	"	"	70	"	"	"	"	"	"	"	"	"	"	Y 330	120	60
"	"	4⁵⁵ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 330	25	60
"	"	7⁰⁰ a. m.	"	"	"	"	Rain	SSW	3	W	4	14°20	13°64	19.08	34.47	Y 330	25	60
164.06	23/8 06	11⁰⁵ p. m.	50°14′	4°24′	60	f. s.	Rain	SW	2	SW	2	14°5	15°70	19.47	35.17	Y 200	25	30
"	"	11¹⁰ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	11⁴⁵ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	150	30
165.06	24/8 06	11⁴⁰ a. m.	49°49′	6°20	72	st.	Cloudy	W	5	W	6	18°5	13°87	19.49	35.21	Y 200	25	30
"	"	11⁵⁰ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	0¹⁵ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	140	60
166.06	25/8 06	2⁰⁰ p. m.	50°40′	9°32′	125	s.	Overcast	SW by S	3	SW	5	17°3	15°74	19.48	35.20	Y 200	200	60
"	"	2¹⁰ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
167.06	26/8 06	8⁰⁰ a. m.	51°28′	11°50′	1220, 1300	y. s.	Cloudy	W by S	5	W	4	17°4	15°61	19.55	35.32	Y 200	300	120
"	"	8¹⁰ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	10³⁰ a. m.	"	"	1300, 1160	"	"	"	"	"	"	"	"	"	"	Y 330	200	120
"	"	1⁰⁵ p. m.	"	"	1160, 1350	"	"	"	"	"	"	"	"	"	"	Y 330	350	60
"	"	2⁴⁵ p. m.	"	"	1350, 1280	"	"	"	"	"	"	"	"	"	"	Y 330	500	90
"	"	4⁵⁵ p. m.	"	"	1280, 1160	"	"	"	"	"	"	"	"	"	"	Y 330	65	60
168.06	26/8 06	10³⁰ p. m.	51°30′	11°37′	390	y. s.	Overcast	SW	3	W	4	16°5	16°59	"	"	Y 330	300	60
"	"	10⁴⁰ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	11⁵⁵ p. m.	"	"	470, 450	"	"	"	"	"	"	"	"	"	"	Y 330	300	300
170.06	29/8 06	4²⁰ p. m.	51°57′	10°27′	77	f. s.	Clear	S	4	SW	3	17°8	15°41	19.53	35.28	Y 330	65	60
"	"	4³⁰ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	5³⁰ p. m.	"	"	80	"	"	"	"	"	"	"	"	"	"	Y 330	150	30
171.06	29/8 06	10¹⁵ p. m.	51°40′	11°06′	178	f. s.	Clear	S	7	S	6	16°0	15°35	19.58	35.37	Y 330	250	60
"	"	10²⁵ p. m.	"	"	170	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
172.06	30/8 06	1⁴⁵ a. m.	51°34′	11°24′	230, 260	f. s.	Cloudy	SSE	5	S	6	15°0	15°80	"	"	Y 330	260	120
"	"	2⁰⁰ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
173.06	30/8 06	5⁴⁰ a. m.	50°31′	11°37′	540, 390	y. s.	Cloudy	S	5	S	6	16°0	15°94	"	"	Y 330	300	120
"	"	5⁴⁵ a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	8¹⁵ a. m.	"	"	390, 450	"	"	"	"	"	"	"	"	"	"	Y 330	200	60
174.06	30/8 06	0⁰⁵ p. m.	51°16′	11°31′	400, 370	f. s.	Cloudy	S by E	4	S	5	18°3	14°40	19.58	35.37	Y 330	300	60
"	"	0²⁵ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
175.06	30/8 06	2⁴⁵ p. m.	51°11′	11°41′	930, 970	y. s.	Cloudy	SSE	5	SSE	4	18°3	16°38	"	"	Y 330	300	60
"	"	2⁵⁰ p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	4²⁰ p. m.	"	"	970, 1010	"	"	"	"	"	"	"	"	"	"	Y 330	1500	60
"	"	5⁵⁰ p. m.	"	"	1010	"	"	"	"	"	"	"	"	"	"	Y 330	25	45
"	"	7⁰⁰ p. m.	"	"	1050	"	"	"	"	"	"	"	"	"	"	Y 330	1050	60
"	"	8⁴⁵ p. m.	"	"	1050, 770	"	"	"	"	"	"	"	"	"	"	Y 330	300	60
"	"	10³⁰ p. m.	"	"	770, 575	"	"	"	"	"	"	"	"	"	"	Y 330	300	60
"	"	11⁵⁵ p. m.	"	"	880	"	"	"	"	"	"	"	"	"	"	Y 330	300	60
"	31/8 06	1³⁵ a. m.	"	"	880, 1030	"	"	SSW	5	S	4	"	"	"	"	Y 330	200	90
"	"	3³⁰ a. m.	"	"	1030	"	"	"	"	"	"	"	"	"	"	Y 330	100	90
176.06	31/8 06	9³⁰ p. m.	49°31′	11°51′	1125, 1075	oz.	Misty	SSW	5	SW	5	18°0	17°22	19.63	35.46	Y 330	300	120

Station Nr.	Date	Hour	Position Lat. N.	Position Long. W.	Depth Meters	Nature of bottom	Weather	Wind Direction 0—12	Wind Force 0—12	Sea Direction 0—12	Sea Force 0—12	Temperature Air	Temperature Surface	Surface Cl ‰	Surface S ‰	Gear	Wire out Meters	Duration of haul in minutes
176.06	31/8 06	9^{35} p. m.	49°31′	11°51′	"	"	Misty	SSW	"	SW	"	18°0	17°22	19.63	35.46	P 100	Surf.	5
177.06	1/9 06	1^{30} a. m.	49°30′	11°38′	550	oz.	Misty	S by W	5	SW	5	16°9	"	"	"	P 100	Surf.	5
"	"	1^{40} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 330	250	120
"	"	4^{10} a. m.	"	"	640	"	"	"	"	"	"	"	"	"	"	Y 330	600	60
"	"	8^{10} a. m.	"	"	1020	"	"	"	"	"	"	"	"	"	"	Y 330	600	60
"	"	10^{30} a. m.	"	"	1020, 990	"	"	"	"	"	"	"	"	"	"	Y 330	250	60
178.06	2/9 06	3^{15} a. m.	48°04′	12°40′	4000	"	Squally	W	3	W	5	16°8	"	"	"	Y 330	300	120
"	"	3^{20} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	5^{40} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 330	600	60
"	"	7^{05} a. m.	"	"	"	"	"	NW	4	"	"	"	"	"	"	Y 330	1000	60
"	"	9^{05} a. m.	"	"	"	"	"	"	"	"	"	18°5	18°40	19.68	35.55	Y 330	1800	120
179.06	2/9 06	9^{30} p. m.	47°20′	12°23′	> 4000	"	Cloudy	NNW	3	NW	4	18°5	19°38	"	"	Y 330	300	120
"	"	9^{40} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	3/9 06	0^{00} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 330	600	120
"	"	3^{40} a. m.	"	"	"	"	"	"	"	"	"	18°5	19°38	19.71	35.61	Y 330	1800	120
180.06	3/9 06	5^{05} p. m.	48°19′	13°53′	> 4000	"	Clear	NNW	1	NW	2	17°0	17°52	19.66	35.52	Y 330	1800	60
"	"	5^{15} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	6^{40} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 330	25	30
"	"	9^{00} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 330	300	60
181.06	4/9 06	7^{50} a. m.	49°22′	12°52′	1350	"	Cloudy	W	2	NW	1	23°5	17°83	"	"	Y 330	300	60
"	"	8^{00} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	9^{10} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 330	600	60
"	"	10^{35} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 330	1800	60
182.06	4/9 06	6^{45} p. m.	50°11′	12°05′	> 2200	"	Cloudy	WSW	2	W	3	17°0	17°62	19.66	35.52	Y 330	600	120
"	"	6^{50} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	8^{00} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 330	300	60
183.06	5/9 06	4^{45} a. m.	51°02′	11°15′	630, 300	f. s.	Squally	W	5	W	5	16°7	16°67	19.61	35.43	Y 330	300	120
"	"	4^{50} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	7^{05} a. m.	"	"	300, 560	"	"	"	"	"	"	"	"	"	"	Y 330	300	150
184.06	7/9 06	4^{10} a. m.	52°02′	11°37′	325, 300	f. s.	Clear	W	6	W	6	14°5	15°54	"	"	Y 330	300	120
"	"	4^{20} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Sur f.	5
185.06	7/9 06	8^{35} a. m.	51°56′	11°55′	620, 630	f. s.	Cloudy	W	6	W	6	18°2	16°14	"	"	Y 330	300	60
"	"	10^{00} a. m.	"	"	630, 550	"	"	"	"	"	"	"	"	"	"	Y 330	600	60
"	"	10^{10} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	11^{35} a. m.	"	"	550	"	"	"	"	"	"	"	"	"	"	Y 330	900	60
"	"	1^{45} p. m.	"	"	600	"	"	"	"	"	"	"	"	"	"	Y 330	900	60
"	"	4^{10} p. m.	"	"	649	"	"	"	"	"	"	"	"	"	"	Y 330	900	120
"	"	6^{45} p. m.	"	"	640, 560	"	"	"	"	"	"	"	"	"	"	Y 330	600	60
"	"	8^{30} p. m.	"	"	560, 500	"	"	"	"	"	"	"	"	"	"	Y 330	300	120
"	"	11^{00} p. m.	"	"	500, 420	"	Squally	NNW	5	"	"	"	"	"	"	Y 330	250	120
"	8/9 06	1^{30} a. m.	"	"	420, 350	"	"	"	"	"	"	"	"	"	"	Y 330	300	120
"	"	3^{50} a. m.	"	"	350, 400	"	"	"	"	"	"	"	"	"	"	Y 330	400	90
186.06	8/9 06	8^{25} p. m.	50°06′	11°06′	600, 570	"	Cloudy	NNE	4	NW	5	15°0	17°22	19.64	35.48	Y 330	300	60
"	"	8^{40} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	9^{50} p. m.	"	"	570, 470	"	"	"	"	"	"	"	"	"	"	Y 330	300	60
"	"	11^{00} p. m.	"	"	470	"	"	"	"	"	"	"	"	"	"	Y 330	65	30
"	"	11^{55} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 330	65	30
"	9/9 06	0^{40} a. m.	"	"	650	"	"	"	"	"	"	"	"	"	"	Y 330	65	30
"	"	1^{35} a. m.	"	"	650	"	"	"	"	"	"	"	"	"	"	Y 330	25	30
"	"	2^{15} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 330	100	30
187.06	9/9 06	7^{00} p. m.	48°25′	9°08′	163, 181	s. st.	Cloudy	NE	4	NE	4	16°2	17°30	19.64	35.48	Y 330	100	60
"	"	7^{10} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	8^{15} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 330	65	30
188.06	9/9 06	11^{10} p. m.	48°12′	8°52′	490	s. st.	Cloudy	NE	4	NE	4	16°7	17°72	19.71	35.61	Y 330	65	30
"	"	11^{50} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 330	65	30
"	"	11^{55} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	10/9 06	1^{10} a. m.	"	"	490	"	"	"	"	"	"	"	"	"	"	Y 330	300	30
189.06	10/9 06	10^{45} a. m.	47°22′	7°55′	3500	"	Clear	ENE	4	E	4	20°5	19°30	19.79	35.75	Y 330	600	60
"	"	10^{50} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	0^{20} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 330	1800	60
"	"	2^{00} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 330	300	60
190.06	11/9 06	0^{45} a. m.	46°30′	7°00′	> 4000	"	Clear	E	4	E	4	20°5	18°82	19.73	35.64	Y 330	65	120
"	"	0^{50} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	3^{00} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 330	300	120
"	"	8^{25} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 330	2700	150
"	"	0^{15} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 330	25	60
"	"	1^{20} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 330	300	15
191.06	11/9 06	8^{00} p. m.	46°58′	6°17′	> 3000	"	Misty	S	2	SE	2	19°5	20°33	19.75	35.69	Y 330	65	60
"	"	8^{10} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
192.06	11/9 06	10^{55} p. m.	47°09′	6°05′	"	"	Clear	S	4	S	3	18°8	19°76	19.69	35.57	Y 330	65	60
"	"	11^{00} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5

Station Nr.	Date	Hour	Position Lat. N.	Position Long. W	Depth Meters	Nature of bottom	Weather	Wind Direction 0—12	Wind Force 0—12	Sea Direction 0—12	Sea Force 0—12	Temperature Air	Temperature Surface	Surface Cl ‰	Surface S ‰	Air	Wire out Meters	Duration of haul in minutes
193.06	12/9 06	1^{45} a. m.	47°13′	6°01′	950, 210	m.	Misty	SSW	3	S	3	19°5	18°5	19.69	35.57	Y 330	65	60
"	"	1^{50} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
194.06	12/9 06	7^{15} a. m.	47°42′	5°30′	130	m.	Misty	S	4	S	3	18°5	17°50	19.57	35.35	Y 330	65	60
"	"	7^{20} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
195.06	13/9 06	10^{30} p. m.	48°20′	5°42′	170	st.	Clear	NNW	1	NW	4	15°2	14°61	19.60	35.41	P 100	Surf.	5
"	"	10^{30} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 330	65	60
"	"	11^{40} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 330	280	60
"	14/9 06	0^{50} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 330	25	30
196.06	14/9 06	1^{00} p. m.	49°24′	3°21′	76	st.	Cloudy	W by S	6	W	7	18°5	16°72	19.47	35.17	Y 330	65	60
"	"	1^{10} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	P 100	Surf.	5
"	"	2^{10} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	65	30
"	"	2^{50} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	120	30
"	"	3^{25} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	Y 200	25	30

3. Supplementary stations of various other vessels.

a. Mediterranean.

Straits of Messina. — Capt. G. Hansen of the "Thor".

Station Nr.	Date	Hour	Position Lat. N.	Position Long. E.	Depth Meters	Nature of bottom	Weather	Wind Direction 0—12	Wind Force 0—12	Sea Direction 0—12	Sea Force 0—12	Temperature Air	Temperature Surface	Surface Cl ‰	Surface S ‰	Air	Wire out Meters	Duration of haul in minutes
278	22/2 11	1^{00} p. m.	38°11.5′	15°37.5′	(230)	g.	"	S	4	S	2	"	14°0	"	"	S 100	15	120
279	23/2 11	7^{00} p. m.	38°11 5′	15°36.5′	(350)	"	"	N	4	N	2	"	13°75	"	"	S 100	30	120
280	26/2 11	5^{20} p. m.	38°11′	15°36.5′	(230)	"	"	NW	5	NW	3	"	13°8	"	"	S 100	15	120
281	1/3 11	3^{44} p m.	38°15′	15°37.5′	5—8	s.	"	NNW	3	NNW	0	"	13°8	"	"	S 100	30	120
"	"	4^{55} p. m.	38°13′	15°36.5′	(200)	g.	"	"	"	"	2	"	13°8	"	"	S 100	10	120
"	"	6^{10} p. m.	"	"	"	"	"	"	"	"	"	"	13°7	"	"	S 100	40	120
"	"	7^{50} p. m.	"	"	"	"	"	"	"	"	"	"	13°7	"	"	S 100	40	120
282	8/3 11	5^{30} p. m.	38°12′	15°37′	(200)	"	"	SSW	3	SSW	2	"	13°8	"	"	S 100	40	90
"	"	7^{15} p. m.	"	"	"	"	"	"	"	"	1	"	13°6	"	"	S 100	40	90
"	"	9^{00} p. m.	"	"	"	"	"	"	2	"	1	"	13°5	"	"	S 100	40	90
"	"	10^{45} p. m.	"	"	"	"	"	"	1	"	"	"	13°5	"	"	S 100	40	180
"	9/3 11	2^{00} a. m.	"	"	"	"	"	"	"	"	"	"	13°5	"	"	S 100	40	90
283	12/3 11	6^{30} p. m.	"	"	"	"	"	W	3	W	2	"	13°7	"	"	S 100	40	180
"	"	9^{45} p. m.	38°12′	15°37.5′	"	s.	"	W	2	W	1	"	13°7	"	"	S 100	40	180
284	14/3 11	6^{00} p. m.	"	"	"	"	"	S	3	S	3	"	13°6	"	"	S 100	40	180
"	"	9^{15} p. m.	"	"	"	"	"	"	4	"	4	"	13°5	"	"	S 100	40	180
"	15/3 11	1^{00} a. m.	38°10.5′	15°34.5′	"	m.	"	S	5	0	0	"	13°3	"	"	S 100	40	90
285	16/3 11	6^{00} p. m.	38°13.5′ 38°15.5′	15°39′ 15°39.5′	(20—150)	s. r.	"	NE	2—3	NE	2	"	13°6	"	"	S 100	40	120
"	"	9^{00} p. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	S 100	40	150
"	"	0^{10} a. m.	38°15.5′ 38°11.5′	15°39.5′ 15°35.5′	(20—200)	s. g.	"	0	0	0	0	"	"	"	"	S 100	30	180
286	18/3 11	6^{30} p. m.	38°12′	15°35.5′	(150)	r.	"	NNE	3	NNE	2	"	13°8	"	"	S 100	40	180
"	"	10^{00} p. m.	38°12.5′	15°34.5′	20—60	s.	"	"	"	"	"	"	13°6	"	"	S 100	40	180
"	19/3 11	1^{00} p. m.	38°10.5′	15°34.5′	10—60	m.	"	0	0	0	0	"	13°6	"	"	S 100	30	90
"	"	2^{30} a. m.	"	"	"	"	"	"	"	"	"	"	"	"	"	S 100	30	90
287	24/3 11	7^{45} p. m.	38°12′	15°34.5′	"	s, r.	"	SSW	2	SSW	1	"	13°8	"	"	S 100	40	90
"	"	9^{30} p. m.	"	"	"	r.	"	"	1	0	0	"	13°8	"	"	S 100	20	90
"	"	11^{45} p. m.	38°10.5′	"	"	m.	"	0	0	0	0	"	13°7	"	"	S 100	40	90
"	25/3 11	1^{30} a. m.	"	"	"	"	"	0	0	0	0	"	13°7	"	"	S 100	20	90
288	30/3 11	7^{00} p. m.	38°10.1′ 38°11.5′	15°34′ 15°34.5′	"	s. r.	"	SW	3	SW	2	"	13°9	"	"	S 100	40	90
"	"	8^{45} p. m.	38°12.5′	"	"	"	"	"	2	"	1	"	13°9	"	"	S 100	40	120
"	"	11^{00} p. m.	38°10.5′	"	"	m.	"	"	1	"	1	"	13°9	"	"	S 100	25	60
"	31/3 11	1^{30} a. m.	"	"	"	"	"	0	0	0	0	"	13°9	"	"	S 100	10	60
289	4/4 11	7^{25} p. m.	38°15′	15°39.5′	"	r.	"	N	2	N	1	"	14°0	"	"	S 100	40	90
"	"	9^{10} p. m.	"	"	"	"	"	"	1	"	1	"	14°0	"	"	S 100	25	90
"	"	1^{55} p. m.	38°15.5′ 38°14.5′	15°39.5′ 15°36′	"	s. r.	"	"	"	"	"	"	14°0	"	"	S 100	10	150

S/S "Pangan", Capt. J. F. Gabe.

Station Nr.	Date	Hour	Position Lat. N.	Position Long. E.	Depth Meters	Nature of bottom	Weather	Wind Direction 0—12	Wind Force 0—12	Sea Direction 0—12	Sea Force 0—12	Temperature Air	Temperature Surface	Surface Cl ‰	Surface S ‰	Air	Wire out Meters	Duration of haul in minutes
274	3/4 11	4^{45} p. m.	39°30′	14°20′	>1000	"	Cloudy	W	7	W	6	"	14°5	"	37.56	S 200	94	30
275	"	8^{30} p. m.	39°05′	14°50′	>1000	"	"	W	8	W	8	"	14°	"	37.90	S 200	94	30
276	4/4 11	11^{20} p. m.	36°30′	19°20′	>3000	"	Clear	SSE	2	WSW	3	"	14°6	"	38.33	S 200	132	35
277	6/4 11	11^{00} p. m.	33°20′	27°30′	>3000	"	"	0	0	0	0	"	15°5	"	38.62	S 200	132	35
296	25/6 11	2^{00} a. m.	32°10′	29°50′	>2000	"	Overcast	NW	3	NW	3	"	22°7	"	38.47	S 200	28	30
297	"	11^{30} p. m.	33°10′	25°03′	>2000	"	Clear	NNW	2	NNW	2	"	22°4	"	38.64	S 200	28	30

Station Nr.	Date	Hour	Position Lat. N.	Position Long.	Depth Meters	Weather	Wind Direction 0—12	Wind Force 0—12	Sea Direction 0—12	Sea Force 0—12	Temperature Surface	Surface S ‰	Gear	Wire out Meters	Duration of haul in minutes
				E.											
298	26/6 11	11^{30} p. m.	34°20′	21°10′	>2000	"	N	2	N	3	22°5	38.82	S200	38	30
339	20/8 11	3^{00} a. m.	40°30′	3°10′	"	"	ENE	3	ENE	3	26°7	"	S200	28	30
"	"	"	"	"	"	"	"	"	"	"	"	"	S150	90	30
340	26/8 11	9^{00} p. m.	35°50′	21°30′	>2000	"	0	0	0	0	27°5	38.80	S200	28	30
"	"	"	"	"	"	"	"	"	"	"	"	"	S150	108	30
341	27/8 11	11^{00} p. m.	34°00′	26°20′	>2000	"	W	2	W	2	26°3	39.29	S200	28	30
"	"	"	"	"	"	"	"	"	"	"	"	"	S150	108	30
384	7/11 11	8^{30} p. m.	32°50′	27°10′	>3000	Squally	W	2	W	2	18°5	39.00	S150	130	30
385	9/11 11	8^{30} p m.	35°10′	18°10′	>3000	Clear	0	0	0	0	16°7	38.91	S150	130	30
				W.											
410	29/12 11	7^{00} p. m.	37°12′	1°18′	>1000	"	0	0	0	0	"	37.30	S150	112	30
				E.											
411	5/1 12	4^{15} a. m.	40°00′	13°42′	>2000	"	NNE	1	NNE	1	"	37.97	S150	112	30
412	7/1 12	6^{30} p. m	34°33′	24°15′	>2000	"	W	7	W	7	"	38.84	S150	112	30

b. Atlantic.

E. of 30° Long. W., N. of 30° Lat. N.

H. M. S. "Ingolf", Capt. Carstensen.

				W.											
264	19/3 11	7^{00} p. m.	38°14′	24°35′	>3200	"	NNW	5	NNW	5	15°6	36.18	S150	25	30
"	"	"	"	"	"	"	"	"	"	"	"	"	S100	47	30
265	20/3 11	7^{00} p. m.	39°22′	22°49′	>5400	"	N	5	N	5	14°7	36.09	S150	25	30
"	"	"	"	"	"	"	"	"	"	"	"	"	S100	47	30
266	21/3 11	7^{00} p. m.	40°47′	21°10′	>4300	"	NW	3	NW	3	14°2	35 95	S150	25	30
"	"	"	"	"	"	"	"	"	"	"	"	"	S100	47	30
267	22/3 11	7^{00} p. m.	42°37′	18°06′	>4500	"	SW	3	SW	3	12°5	35.68	S150	25	30
"	"	"	"	"	"	"	"	"	"	"	"	"	S100	47	30
268	24/3 11	4^{30} a. m.	45°44′	13°20′	>4500	"	WNW	3	WNW	3	11°6	35.64	S150	25	30
"	"	"	"	"	"	"	"	"	"	"	"	"	S100	47	30
269	24/5 11	7^{30} p. m.	46°44′	11°20′	>4700	"	E	1	E	1	11°5	35.61	S150	25	30
"	"	"	"	"	"	"	"	"	"	1	"	"	S100	47	30

S/S "St. Croix", Capt. E. Kall.

270	15/2 11	10^{05} p. m.	47°01′	19°03′	>4200	Rain	SW	5	SW	6	12°1	35.69	S150	116	33

Schooner "Agent Petersen", Capt. J. Frederiksen.

305	23/6 11	2^{00} p. m.	45°54′	26°42′	>2400	"	NE	1	NE	3	"	35.51	S100	44	150
306	24/6 11	0^{00} a. m.	45°50′	26°30′	>2400	"	NE	1	NE	2	"	"	S100	48	60
307	24/6 11	6^{00} a. m.	45°32′	25°50′	>2400	"	N	1	NE	2	"	35.88	S100	57	360

Schooner "Caroline Kock", Capt. H. Rasmussen.

309	6/2 11	5^{30} p. m.	38°06′	18°24′	>4700	"	S	1	"	large swell	"	36.11	S100	38	60
310	7/2 11	7^{30} p. m.	37°50′	18°50′	>2400	"	SSE	1	"	"	"	36.09	S100	38	60
311	9/2 11	4^{00} p. m.	37°08′	15°50′	>1500	"	W	2	"	"	"	36.11	S100	38	60
317	5/6 11	1^{20} p. m.	48°10′	26°20′	>3500	"	W	2	W	swell	"	35.57	S100	48	30
318	5/6 11	11^{00} p. m.	48°15′	25°30′	>3500	"	S	1	W	swell	"	35.46	S100	48	45
319	5/6 11	2^{00} a. m.	48°15′	25°15′	>3500	"	S	1	W	swell	"	"	S100	38	90
320	9/6 11	5^{00} p. m.	47°10′	23°00′	>3500	"	E	2	E	3	"	35.59	S100	48	60
321	9/6 11	5^{30} p. m.	47°20′	22°30′	>3500	"	SSW	2	E	swell	"	35.66	S100	48	30
322	11/6 11	2^{30} p. m.	47°40′	17°10′	>4200	"	W	3	NW	3	"	35.57	S100	48	50
323	11/6 11	3^{00} a. m.	47°30′	16°49′	>4200	"	NW	2	NW	swell	"	35.55	S100	48	150
324	11/6 11	8^{00} a. m.	47°35′	16°35′	>4200	"	W	2	NW	swell	"	35.66	S100	38	120

S/S "St. Jan", Capt. K. Ingemann.

325	7/6 11	2^{00} p. m.	37°48′	25°25′	>350	"	N	5	NE	5	19°5	"	S200	35	35
326	8/6 11	3^{00} a. m.	36°36′	29°00′	>3000	"	N	2	N	2	20°5	36.35	S200	35	40
"	"	"	"	"	"	"	"	"	"	"	"	"	S200	17	40
331	2/7 11	8^{00} p. m.	35°50′	29°53′	>3500	"	ENE	2	ENE	3	22°5	36.33	S200	35	30
"	"	"	"	"	"	"	"	"	"	"	"	"	S200	17	30

Station Nr.	Date	Hour	Position Lat. N.	Position Long. W.	Depth Meters	Wind Direction 0—12	Wind Force 0—12	Sea Direction 0—12	Sea Force 0—12	Temperature Surface	Surface S ‰	Gear	Wire out Meters	Duration of haul in minutes
S/S "St. Thomas", Capt. Berg.														
332	5/7 11	11²⁰ a. m.	45°35′	24°40′	>2500	WSW	2	WSW	2	18°0	35.68	S 200	21	20
"	"	"	"	"	"	"	"	"	"	"	"	S 100	28	20
333	5/7 11	9⁰⁰ p. m.	44°50′	26°45′	>2400	SW	4	SW by W	5	17°5	35.86	S 200	16	30
"	"	"	"	"	"	"	"	"	"	"	"	S 100	30	30
338	18/8 11	8¹⁵ p. m.	45°40′	21°45′	>3500	E	3	NE by E	3	18°5	35.11	S 200	16	25
"	"	"	"	"	"	"	"	"	"	"	"	S 100	30	25
Schooner "Anne", Capt. P. Mikkelsen.														
358	1/4 11	1⁸⁰ a. m.	32°50′	10°40′	>3300	SW	1	NW	3	16°0	36.38	S 100	38	90
359	1/4 11	12⁰⁰ p. m.	33°10′	10°50′	>3500	SW	1	NW	3	16°5	36.40	S 100	48	240
360	2/4 11	6⁰⁰ a. m.	33°00′	10°34′	>3500	S	1	W	1	16°5	36.44	S 100	48	60
361	5/4 11	3⁰⁰ a. m.	31°05′	16°40′	>4500	N	1	NNW	3	17°5	"	S 100	38	90
362	5/4 11	4⁸⁰ p. m.	31°03′	16°43′	>4500	N	1	NNW	3	"	"	S 100	38	120
363	5/4 11	6⁸⁰ p. m.	31°02′	16°45′	>4500	NW	2	NNW	3	"	36.74	S 100	?	30
364	6/4 11	6⁰⁰ a. m.	30°25′	17°00′	>4000	N	1	N	1	18°5	36.65	S 100	48	60
S/S "Florida", Capt. H. Andersen.														
375	21/7 11	3⁴⁰ a. m.	40°11′	12°11′	>3500	NW	1	NW	1	19°5	35.97	S 200	15	30
"	"	"	"	"	"	"	"	"	"	"	"	S 100	30	30
376	22/7 11	8¹⁰ a. m.	34°41′	16°14′	>3500	NE	2	N	2	22°3	36.33	S 200	15	30
"	"	"	"	"	"	"	"	"	"	"	"	S 100	30	30
377	23/7 11	8⁰⁵ p. m.	31°23′	18°08′	>4300	0	0	N	2	21°0	36.74	S 200	15	30
"	"	"	"	"	"	"	"	"	"	"	"	S 100	30	30
382	22/10 11	6⁰⁵ p. m.	34°21′	16°24′	>1100	SW	2	NW	3	21°0	36.33	S 100	22	30
383	23/10 11	6⁰⁵ p. m.	37°16′	14°09′	>3500	NE	2	NNW	3	19°0	36.27	S 100	30	30
H. M. S. "Ingolf", Capt. H. Rørbye.														
398	26/10 11	12⁴⁰ a. m.	36°48′	14°22′	>2600	NW by W	2	NW by W	2	19°3	36.29	S 200	Surf.	30
"	"	"	"	"	"	"	"	"	"	"	"	S 150	56	30
399	28/10 11	9¹⁰ p. m.	34°23′	15°31′	>2600	0	"	"	"	20°6	36.45	S 200	Surf.	30
"	"	"	"	"	"	"	"	"	"	"	"	S 150	56	30
400	30/10 11	9³⁵ p. m.	32°10′	17°20′	>4500	ENE	3	E	3	21°3	36.76	S 200	Surf.	30
"	"	"	"	"	"	"	"	"	"	"	"	S 150	56	30
401	1/11 11	12⁸⁰ a. m.	30°20′	19°05′	>4700	ENE	3	ENE	3	22°1	37.03	S 200	Surf.	30
"	"	"	"	"	"	"	"	"	"	"	"	S 150	56	30
S/S "St. Jan", Capt. K. Ingemann.														
413	23/11 11	7¹⁵ p. m.	38°06′	25°37′	>2500	WSW	4	W	"	18°0	36.08	S 200	17	30
"	"	"	"	"	"	"	"	"	"	"	"	S 200	35	30

Danish Oceanographical Expeditions 1908—1910, vol. I [Johs Schmidt].

STATIONS OF THE „THOR“ IN 1908—1910
AND SUPPLEMENTARY STATIONS.

II.

HYDROGRAPHY

1.

Hydrographical Observations

CONTENTS

page

1. Observations made during the "Thor" Expeditions to the Mediterranean 55
   a) Winter Expedition 1908—1909 55
   b) Summer Expedition 1910 60
2. Observations made during the "Thor" Expeditions of 1905 and 1906 in the Atlantic S. of Ireland 70
3. Temperature Observations made in 1911 in the Straits of Messina 71
4. Surface Observations 72
   a) by Research Steamer "Thor" 72
   b) by Danish Merchant Vessels 73
   c) by Foreign Merchant Vessels 74

ABBREVIATIONS

m ... the depth in meters.

$t°$ ... the corrected temperature in Centigrade. For the correction see J. N. Nielsen's paper in this Report.

$Cl\,‰$ ... the chlorine } weight in grammes in 1000 gms. sea water.
$S\,‰$ ... the salinity }

σt ... $= 1000\ (s_t - 1)$, where s_t is the specific gravity calculated at the observed temperature and salinity under a pressure of 1 atmosphere.

O_2 ... the amount of oxygen observed at the depth m, i. e. the amount of oxygen measured in cc. at 0°, 760 mm. pressure and dryness, that is, absorbed in 1000 cc. of the sea water.

O'_2 ... the amount of oxygen measured in cc. at 0°, 760 mm. pressure and dryness, that ought to be absorbed in 1000 cc. of the sea water in question, the water being saturated with atmospheric air under 760 mm. pressure. When the determinations of oxygen have been carried out according to Winkler's method, O'_2 is calculated by means of J. P. Jacobsen's tables.

$\frac{100\ O_2}{O'_2}$ ... the amount of oxygen found at the depth m, expressed in per cent. of the O'_2.

p_H ... the Hydrogen ion exponent (see S. Palitzsch's paper in this Report).

I. Observations made during the "Thor" Expeditions to the Mediterranean.

a) Winter Expedition 1908—1909.

Stat. **4.** 1. Dec. 1908. 2^{00} p. m. 45°20 N, 7°42′ W; depth > 4000 m.

m	$t°$	Cl ‰	S ‰	σ_t	O'_2	O_2	$\frac{100\ O_2}{O'_2}$	p_H
0	15,6							
100	13,3	19,78	35,73	26,92				
1000	9,9	78	73	27,56				

Stat. **11.** 16. Dec. 1908. 2^{00} p. m. 36°57′ N, 18°16′ E; depth > 3700 m.

m	$t°$	Cl ‰	S ‰	σ_t	O'_2	O_2	$\frac{100\ O_2}{O'_2}$	p_H
0	16,60	21,07	38,06	27,98				
10	62	06	04	96				
25	62	05	03	95				
50	62	05	03	95				
75	62	06	04	96				
85	15,82	09	10	28,19				
100	42	13	17	33				
150	14,45	33	53	83				
200	66	46	71	92				
300	30	48	80	29,07				
400	17	47	78	09				
500	13,94	42	71	08				
600	84	42	69	10				
800	74	42	69	12				
1000	59	41	68	13				
1250		42	69					
1500		40	66					

Stat. **15.** 22. Dec. 1908. 11^{00} a. m. 40°04′ N, 19°06′ E; depth 1000 m.

m	$t°$	Cl ‰	S ‰	σ_t	O'_2	O_2	$\frac{100\ O_2}{O'_2}$	p_H
0	15,20							
10	43	21,17	38,24	28,39				
25	41	18	26	41				
50	21	19	28	47				
75	14,99	19	28	52				
100	66	36	58	83				
150	25	37	60	93				
200	19	41	68	29,00				
300	00	41	68	04				
400	13,87	44	73	12				
500	77	40	66	08				
600	78	40	66	08	5,72	5,02	87,8	
800	73	40	66	09	73	4,55	79,4	
950	51	39	64	12	75	5,04	87,7	

Stat. **18.** 30. Dec. 1908. 7^{30} p. m. 37°51′ N, 23°14′ E; depth 220 m.

m	$t°$	Cl ‰	S ‰	σ_t	O'_2	O_2	$\frac{100\ O_2}{O'_2}$	p_H
0	15,20	21,26	38,40	28,57				
10	40	29	46	57				
25	40	28	44	55				
50	41	28	44	54				
75	27	29	46	60				
85	14,58	30	48	76				
100	13,52	35	57	29,06				
125	12	34	55	13				
150	12,85	36	58	22				
200	78	35	57	21				

Stat. **24.** 16. Jan. 1909. 5^{20} p. m. 40°14′ N, 12°23′ E; depth > 3700 m.

m	$t°$	Cl ‰	S ‰	σ_t	O'_2	O_2	$\frac{100\ O_2}{O'_2}$	p_H
0	14,15	21,00	37,94	28,44				
10	20	20,98	90	40				
25	10	99	92	44				
50	02	21,00	94	46				
75	00	04	38,01	53				
100	13,77	04	19	72				
125	74	19	28	79				
137½	72							
144	67	19	28	81				
150	62	26	40	91				
175	62	25	39	90				
187½	13,71	21,28	38,44	28,92				
194	80	28	44	90				
200	85	29	46	91				
300	87	37	60	29,01				
400	90	29	64	04				
500	91	41	68	06				
550	89							
600	84	29	64	05	5,72	4,31	75,4	
800	55	35	57	05	74	32	75,3	
1000	49	32	51	03	76	18	72,6	
1250	40	28	44	28,99	77	20	72,8	
1500	25	29	46	29,04	78	20	72,7	
1800	29	26	40	28,98	78	26	73,7	
2000	33	28	44	29,00	78	25	73,6	
2130	36	26	40	28,96	77	29	74,4	

Stat. **30.** 21. Jan. 1909. 8^{00} a. m. 41°15′ N, 11°55′ E; depth > 1800 m.

m	$t°$	Cl ‰	S ‰	σ_t	O'_2	O_2	$\frac{100\ O_2}{O'_2}$	p_H
0	13,60	21,03	37,99	28,60				
10	68	03	99	58				
25	69	01	95	55				
50	71	01	95	55				
75	72	13	38,17	71				
78	72							
81	62							
87½	59							
100	62	18	26	81				
125	60	23	35	88				
150	81	27	42	89				
200	82	31	49	95				
300	87	35	57	98				
500	90	40	66	29,05				
600	84	41	68	08				
700	71	40	66	09				
800	49	34	55	06				
1000	40	32	51	05				
1250	30	31	49	06				
1500	22	31	49	07				
1800	18	26	40	01				

Stat. **31.** 21. Jan. 1909. 10^{00} p. m. 41°44′ N, 10°52′ E; depth 1420 m.

m	$t°$	Cl ‰	S ‰	σ_t	O'_2	O_2	$\frac{100\ O_2}{O'_2}$	p_H
0	13,00	21,06	38,04	28,77				
10	07	06	04	75				
25	08	06	04	75				
50	09	06	04	75				
56	15							
59	34							
62	42	16	22	82				
75	54	21	31	86				
100	62	26	40	90				
150	81	31	49	95				
200	85	36	58	29,01				
300	92	40	66	05				
400	87	39	64	04				
500	76	39	64	07				
600	57	36	58	07				
800	37	32	51	05				
1000	25	28	44	02				
1250	20	29	46	05				
1400	22	28	44	02				

Stat. **32.** 22. Jan. 1909. 2 p. m. 42°45′ N, 9°50′ E; depth 640 m.

m	$t°$	Cl ‰	S ‰	σ_t	O'_2	O_2	$\frac{100\ O_2}{O'_2}$	p_H
0	13,70	20,99	37,92	28,52				
10	78	21,00	94	51				
25	78	20,99	92	50				
50	78	99	92	50				
75	79	99	92	50				
100	80	21,01	95	53				
125	77							

m	$t°$	Cl ‰	S ‰	σ_t	O'_2	O_2	$\frac{100\ O_2}{O_2}$	p_H
150	13,55	21,10	38,12	28,71				
175	55							
200	63	21	31	84				
400	86	38	62	29,03				
600	50	37	60	09	5,75	4,39	76,4	

Stat. **33**. 22. Jan. 1909. 4^{00} p. m. 43°04′ N, 9°35′ E; depth 150 m.

0	13,00	21,08	38,08	28,79				
10	00	08	08	79				
25	07	08	08	78				
50	15	10	12	79				
75	25	11	13	78				
100	33	11	13	76				
140	52	16	22	80				

Stat. **35**. 28. Jan. 1909. 9^{00} p. m. 43°36′ N, 7°36′ E; depth > 2000 m.

0	12,80	21,06	38,04	28,81				
10	89	05	03	78				
25	90	04	01	76				
50	94	04	01	75				
75	96	06	04	77				
100	96	06	04	77				
200	93	15	21	90				
250	95	15	21	90				
300	13,26	27	42	29,01				
400	38	30	48	02				
450	55	33	53	02				
500	50	32	51	02				
600	32	32	51	07	5,78	4,33	74,9	
800	12	30	48	08	80	32	74,5	
1000	04	28	44	06	81	37	75,2	
1250	00	27	42	06	81	37	75,2	
1500	12,96	27	42	07	81	50	77,5	
2000	13,05	27	42	05	81	45	76,6	

Stat. **37**. 30. Jan. 1909. 5^{00} p. m. 41°56′ N, 6°18′ E; depth > 2600 m.

0	12,40	21,17	38,24	29,04				
10	48	18	26	04				
25	48	17	24	02				
50	49	17	24	02				
75	50	17	24	02				
100	53	19	28	04				
150	55	20	30	06				
200	67	22	33	06				
225	13,15	28	44	04				
250	11	28	44	05				
300	08	30	48	08				
400	01	27	42	06				
500	12,97	27	42	07				
600	94	25	39	05				
800	92	25	39	05				
1000	91	25	39	05				
1500	94	23	35	02				
2000	13,01	23	35	00				

Stat. **38**. 31. Jan. 1909. 9^{00} p. m. 40°45′ N, 9°50′ E; depth 105 m.

0	12,80	21,15	38,21	28,93				
10	81	13	17	90				
25	81	14	19	92				
50	82	13	17	90				
75	83	14	19	92				
100	83	14	19	92				

Stat. **39**. 1. Feb. 1909. 9^{00} a. m. 39°41′ N, 10°02′ E; depth 1750 m.

0	13,20	21,02	37,97	28,67				
10	26	20,97	88	59				
25	26	98	90	60				
50	27	97	88	58				
56	28							

m	$t°$	Cl ‰	S ‰	σ_t	O'_2	O_2	$\frac{100\ O_2}{O_2}$	p_H
63½	13,44	21,04	38,01	28,64				
67½	72							
75	73	19	28	79				
100	75	24	37	86				
150	81	31	49	95				
200	92	36	58	99				
300	97	41	68	29,05				
350	94	41	68	06				
400	87	39	64	04				
500	80	39	64	06				
600	64	39	64	09	5,74	4,23	73,7	
700	51	35	57	06	75	18	72,6	
800	41	33	53	05	77	20	72,8	
1000	27	31	49	06	78	21	72,8	
1250	20	29	46	05	79	20	72,6	
1500	17	29	46	05	79	21	72,7	
1700	16	27	42	03	79	29	74,1	

Stat. **40**. 1. Feb. 1909. 8^{00} p. m. 39°10′ N, 9°40′ E; depth 235 m.

0	13,20	20,99	37,92	28,63				
10	58	96	86	51				
25	57	95	84	49				
50	54	96	86	52				
75	65	21,11	38,13	70				
100	62	21	31	85				
130	71	23	35	86				
150	77	25	39	87				
200	89	33	53	95				
230	95	36	58	99				

Stat. **42**. 2. Feb. 1909. 7^{00} p. m. 38°58′ N, 9°37′ E; depth 1120 m.

0	13,30	20,94	37,83	28,54				
10	39	93	81	50				
25	39	93	81	50				
50	40	94	83	52				
67½	52	97	88	53				
75	82	21,16	38,22	74				
100	80	22	33	83				
150	81	28	44	90				
200	84	34	55	98				
250	93	34	55	96				
300	94	39	64	29,03				
400	88	39	64	04				
500	80	39	64	06				
600	64	39	64	09	5,74	4,20	73,2	
700	54	34	55	04				
800	48	33	53	04	76	16	72,2	
900	38	33	53	06				
1000	19	31	49	08	79	15	71,7	

Stat. **43**. 3. Feb. 1909. 7^{00} a. m. 38°14′ N, 8°42′ E; depth > 2000 m.

0	13,80	20,69	37,38	28,08				
10	97	69	38	04				
25	97	71	41	07				
50	98	71	41	07				
67½	14,04	72	43	08				
75	16	87	70	25				
87½	13,94	93	81	39				
100	68	21,01	95	55				
150	44	36	38,58	29,10				
175	65	23	35	28,87				
200	96	31	55	96				
300	14,01	40	66	29,03				
400	13,95	40	66	04				
500	85	41	68	08				
600	67	36	58	05	5,73	4,19	73,2	
700	51	34	55	05	76	23	73,5	
800	33	32	51	06	78	19	72,5	
1000	18	28	44	03	79	21	72,7	
1250	19	30	48	06	79	20	72,6	
1500	02	24	37	01	81	35	74,9	
1950	01	24	37	01	81	47	77,0	

m	$t°$	Cl ‰	S ‰	σ_t	O'_2	O_2	$\frac{100\ O_2}{O'_2}$	p_H
	Stat. **45**. 6. Feb. 1909. 8 p. m. 37° 28′ N, 8° 13′ E; depth 2150 m							
0	14,00	20,48	37,00	27,75				
10	14	47	36,98	70				
25	12	47	98	70				
50	12	47	98	70				
75	13	49	37,01	73				
100	44	57	16	78				
150	45	76	50	28,03				
175	13,87	87	70	31				
200	53	21,03	99	62				
250	93	29	38,46	90				
300	14,01	35	57	95				
400	13,99	38	62	29,01				
500	90	38	62	03				
600	68	38	62	07	5,73	4,14	72,3	
700	39	28	44	28,99	77	13	71,6	
800	20	29	46	29,05	79	14	71,5	
1000	02	26	40	04	81	29	73,9	
1250	12,94	23	35	02	82	36	74,9	
1500	96	23	35	01	81	39	75,2	
2000	99	23	35	00	81	50	77,5	
	Stat. **46**. 7. Feb. 1909. 4 p. m. 37° 17′ N, 6° 00′ E; depth 1930 m.							
0	14,20	20,44	36,92	27,65				
10	29	42	89	60				
25	30	42	89	60				
50	40	47	98	64				
75	35	58	37,18	81				
100	24	63	27	90				
150	03	93	81	28,37				
175	13,35	21,07	38,06	71				
200	15	12	15	82				
250	22	24	37	97				
300	56	29	46	97				
400	43	29	46	29,00				
450	27	30	48	03				
500	08	25	39	02				
600	12,92	24	37	03	5,82	4,17	71,7	
700	93	24	37	03	82	20	72,2	
800	93	24	37	03	82	26	73,2	
1000	94	22	33	01	82	32	74,2	
1250	92	25	35	02	82	36	74,9	
1500	95	22	33	00	82	40	75,6	
1900	13,00	22	33	28,99	81	55	78,3	
	Stat. **46 a**. 8. Feb. 1909. 6$\frac{45}{}$ p. m. 37° 09′ N, 4° 24′ E; depth > 2000 m							
2000	13,01	21,26	38,40					
	Stat. **47**. 8. Feb. 1909. 6 p. m. 36° 55′ N, 3° 12′ E: depth > 2000 m.							
0	14,50	20,35	36,76	27,47				
10	53	36	78	46				
25	51	36	78	47				
50	50	36	78	47				
75	47	35	76	46				
100	61	40	85	50				
150	10	69	37,38	28,02				
167½	05	68	36	02				
175	23	72	43	03				
200	13,95	95	84	41				
225	18	21,08	38,08	76				
250	04	16	22	90				
300	06	22	33	98				
400	06	26	40	29,03				
600	99	25	39	04	5,81	4,14	71,2	
1000	12,91	24	37	03	82	32	74,2	
1500	94	24	37	03	82	43	76,1	
2000	13,00	25	39	03	81	46	76,8	

m	$t°$	Cl ‰	S ‰	σ_t	O'_2	O_2	$\frac{100\ O_2}{O'_2}$	p_H
	Same locality, 10. Feb. 1909.							
75	14,41	20,35	36,76	27,48				
100	41	38	82	52				
150	21	63	37,27	90				
	Stat. **50**. 16. Feb. 1909. 11 p. m. 37° 02′ N, 1° 17′ E; depth > 2000 m.							
0	13,40	20,70	37,39	28,18				
10	46	64	29	08				
25	46	66	32	11				
37½	55	69	38	13				
50	14,03	91	75	33				
67½	04	21,04	38,03	54				
71½	13,87	04	01	55				
75	70	01	37,95	55				
87½	36	10	38,12	75				
100	20	11	13	79				
125	02	10	12	82				
150	12,97	13	17	87				
175	93	16	22	92				
200	94	20	30	98				
225	97	22	33	29,00				
250	13,02	23	35	00				
300	04	26	40	04				
400	03	26	40	04				
500	12,99	31	49	12				
600	94	26	40	06				
800	93	24	37	03				
1000	91	26	40	06	5,82	4,32	74,3	
1250	92	24	37	03	82	36	74,9	
1500	93	26	40	06	82	44	76,3	
2000	99	29	46	09	81	48	77,1	
	Stat. **51**. 17. Feb. 1909. 11 p. m. 36° 27′ N, 0° 37′ W; depth > 2000 m.							
0	14,00	20,31	36,69	27,51				
5	09	31	69	49				
10	13	32	71	49				
17½	07	35	76	55				
25	00	41	87	64				
33	19	51	37,05	75				
37½	36							
50	36	68	36	95				
75	22	81	59	28,16				
100	02	95	84	40				
125	13,82	21,00	94	51				
150	49	09	38,10	71				
175	17	14	19	85				
200	12,97	15	21	90				
250	95	18	26	95				
300	94	21	31	99				
400	13,04	27	42	29,06				
500	05	28	44	06				
600	00	28	44	07	5,81	4,11	70,8	
800	12,94	28	44	09	82	22	72,5	
1000	94	26	40	06	82	28	73,6	
1500	94	27	42	07	82	40	75,6	
2000	99	27	42	06	81	45	76.6	
	Stat. **52**. 18. Feb. 1909. 8 a. m. 35° 55′ N, 1° 02′ W; depth > 2000 m.							
0	14,35	20,30	36,67	27,41				
5	38							
10	38	30	67	41				
25	38	30	67	41				
50	38	32	71	44				
75	36	38	82	53				
87½	09							
100	05	52	37,07	79				
150	13,98	21,02	97	28,50				
167½	43							
175	29	09	38,10	75				
187½	03							
200	00	15	21	89				
250	12,96	21	31	98				

m	$t°$	Cl ‰	S ‰	σ_t	O'_2	O_2	$\frac{100\ O_2}{O'_2}$	p_H
300	12,94	21,21	38,31	28,99				
400	13,02	28	44	29,07				
500	01	28	44	07				
600	12,96	26	40	05	5,81	4,10	70,6	
800	93	27	42	08				
1000	91	25	39	05	82	35	74,8	
1500	93	26	40	06				
2000	99	27	42	06	81	48	77,1	

Stat. **53**. 18. Feb. 1909. 3 p. m. 36°13′ N, 1°28′ W; depth > 2000 m.

0	13,87	20,62	37,25	27,97				
5	86	64	29	28,00				
10	84	64	29	00				
$17\frac{1}{2}$	82							
21	82							
23	86							
24	91							
25	99							
25	14,07	82	61	20				
26	07							
50	02	94	83	39				
75	13,89	21,03	99	54				
100	55	07	38,06	67				
150	16	13	17	83				
200	03	17	24	91				
225	12,91	15	21	91				
250	90	20	30	99				
300	94	22	33	29,01				
350	98	25	39	04				
400	13,04	27	42	06				
500	00	27	42	06				
600	12,97	27	42	07				
800	93	25	39	05				
1000	94	25	39	05				
1500	94	25	39	04				

Stat. **54**. 19. Feb. 1909. 1 a. m. 36°30′ N, 1°54′ W; depth 1450 m.

0	13,50	20,75	37,48	28,23				
10	39	80	57	32				
25	40	81	59	34				
50	58	85	66	36				
75	72	21,04	38,01	58				
100	36	09	10	74				
150	08	15	21	87				
200	12,97	17	24	93				
250	91	20	30	99				
300	92	22	33	29,01				
400	13,00	24	37	02				
500	12,97	25	39	04				
600	95	25	39	04	5,82	4,37	75,1	
800	92	23	35	02	82	39	75,4	
1000	93	24	37	03	82	41	75,8	
1400	95	24	37	02	81	39	75,6	

Stat. **58**. 20. Feb. 1909. 1 p. m. 36°36′ N, 4°24′ W; depth 85 m.

0	13,65	20,37	36,78	27,65				
5	86	37	78	61				
10	99	48	37,00	75				
25	14,11	77	52	28,13				
50	13,94	93	81	39				
75	84	21,05	38,03	58				

Stat. **59**. 20. Feb. 1909. 10 p. m. 36°02′ N, 4°24′ W; depth 1260 m.

0	14,50	20,17	36,44	27,21				
10	51	15	40	18				
25	27	34	74	49				
50	04	74	37,47	28,10				
75	03	87	70	28				
100	13,70	21,03	99	58				
125	13,35	21,06	38,04	28,69				
150	03	12	15	85				
200	12,91	15	21	91				
250	92	21	31	99				
300	99	22	33	29,00				
400	13,04	25	39	03				
500	01	25	39	03				
600	12,98	25	39	04	5,81	4,09	70,4	
800	95	23	35	02	82	17	71,7	
1000	96	25	39	04	81	23	73,8	
1240	93	26	40	06	82	36	74,9	

Stat. **60**. 21. Feb. 1909. 10^{00} a. m. 36°02′ N, 5°15′ W; depth 900 m.

0	14,50	20,18	36,45	27,22				
10	48	16	42	20				
25	38	23	55	31				
50	02	66	37,32	99				
75	01	75	48	12				
100	13,82	21,05	38,12	58				
125	88	20,88	37.72	33				
$137\frac{1}{2}$	88							
150	70	21,05	38.03	28,61				
150	23	10	12	78				
175	20	10	12	78				
200	00	18	26	94				
250	12,92	20	30	98				
300	93	21	31	99				
400	13,02	23	35	29,00				
500	03	26	40	04				
600	00	26	40	04	5,81	3,92	67,5	
700	12,90	23	35	03				
850	91	24	37	03	82	4,10	70,5	

Stat. **61**. 21. Feb. 1909. 1 p. m. 35°57′ N, 5°35′ W; depth 740 m.

0	14,65	20,21	36,51	27,18				
10	09	41	87	58				
25	13,99	50	37,03	78				
50	81	65	30	28,02				
75	70	80	57	25				
100	66	94	83	46				
125	39	21,06	38,04	68				
150	15	12	15	82				
200	03	14	19	88				
250	12,99	20	30	97				
300	98	20	30	97				
400	98	24	37	29,02				
500	96	24	37	02				
600	97	24	37	02	5,81	4,13	71,1	
700	95	24	37	03	82	14	71,1	

Stat. **62**. 21. Feb. 1909. 6 p. m. 35°45′ N, 5°59′ W; depth 58 m.

0	14,90	20,11	36,33	27,04				
10	99	10	31	00				
25	15,00	10	31	00				
50	00	11	33	01				

Stat. **63**. 21. Feb. 1909. 11^{30} p. m. 35°50′ N, 6°03′ W; depth 490 m.

0	14,95	20,08	36,27	26,98				
10	96	08	27	98				
25	98	07	26	96				
50	92	08	27	98				
75	90	08	27	99				
100	89	08	27	99				
150	71	12	35	27,09				
200	41	26	60	35				
250	13,94	57	37,16	89				
300	57	82	61	28,31				
400	25	21,05	38,03	70				
475	24	06	04	72				

m	$t°$	Cl ‰	S ‰	σ_t	O'_2	O_2	$\frac{100\,O_2}{O'_2}$	p_H
Stat. **64**. 22. Feb. 1909. 9^{30} p. m. 36° 32′ N, 6° 26′ W; depth 40 m.								
0	14,00	20,05	36,22	27,15				
10	00	04	20	14				
25	13,98	03	18	12				
40	88	05	22	17				
Stat. **65**. 24. Feb. 1909. 4 p. m. 35° 53′ N, 7° 26′ W; depth 1300 m.								
0	15,70	20,13	36,36	26,89				
10	68	14	38	90				
25	61	11	33	88				
50	61	11	33	88				
75	61	11	33	88				
100	53	12	35	90				
150	05	07	26	95				
163	14,56	01	15	97				
175	32	19,94	02	92				
200	13,94	92	35,99	98				
250	47	87	90	27,01				
300	06	83	82	04				
350	12,53	78	73	07				
400	11,89	74	66	14				
500	41	68	55	15				
600	10,92	69	57	26	6,16	4,35	70,6	
800	73	84	84	50	18	3,99	64.4	
1000	24	84	84	58	25	4,04	64,7	
1125	22	92	99	70				
1188	22	97	36,08	77				
1250	21	99	11	80	23	4,20	67,4	
1250	21						67,2	
Stat. **66**. 25. Feb. 1909. 7 a. m. 36° 16′ N, 6° 52′ W; depth 735 m.								
0	14,80	20,07	36,26	27,00				
10	90	06	24	26,96				
25	90	05	22	95				
50	91	04	20	94				
75	92	10	31	27,01				
100	91	09	29	01				
150	87	10	31	02				
200	62	06	24	02				
225	12	19,97	08	01				
250	13,63	94	02	07				
300	03	85	35,86	07				
350	12,15	80	77	13				
400	11,68	74	66	16				
500	31	72	62	22				
600	57	86	88	37				
650	95	20,01	36,15	51				
700	12,15	45	94	28,08	5,96	4,63	77,7	
Stat. **68**. 27. Feb. 1909. 5 p. m. 36° 39′ N, 7° 21′ W; depth 550 m.								
0	14,80	20,06	36,24	26,98				
25	80	06	24	98				
50	81	06	24	98				
100	78	06	24	99				
150	05	19,97	08	27,02				
200	13,36	87	35,90	03				
250	04	83	82	04				
300	12,59	79	75	07				
350	02	77	71	15				
400	11,74	69	57	10				
475	12,08	95	36,04	39				
500	50	20,06	24	46				
525	13.08	16	42	49				
535	23	19	47	50				
Stat. **69**. 28. Feb. 1909. 5 p. m. 36° 13′ N, 9° 44′ W; depth > 3500 m.								
0	14,79	20,07	36,26	27,00				
25	98	07	26	26,96				
50	90	07	26	98				
100	14,88	20,04	36,20	26,94				
150	03	19,96	06	27,02				
200	13,11	85	35,86	05				
300	12,28	78	73	12				
400	11,68	75	68	19				
500	10,92	69	57	26				
600	89	75	68	34				
800	94	89	93	53				
1000	11,69	20,15	36,40	76	6,03	4,29	71,2	
1200	32	13	36	80				
1500	8,23	19,79	35,75	84				
2000	5,04	48	19	84	7,02	5,38	76,7	
Stat. **71**. 4 March 1909. 1^{30} p. m. 39° 35′ N, 9° 45′ W; depth > 1300 m.								
0	12,76	19,84	35,84	27,11				
10	76							
25	68	83	82	11				
50	73	82	81	09				
100	74	83	82	10				
150	75	82	81	09				
200	60	83	82	15				
250	29	86	88	23				
300	11,82	78	78	24				
400	45	78	73	28				
600	49	87	90	40				
800	48	96	36,06	53				
1150	18	96	11	62				
Stat. **74**. 8. March 1909. 10 p. m. 44° 21′ N, 7° 55′ W; depth > 3000 m								
0	11,50	19,72	35,62	27,19				
25	55	71	61	17				
50	55	71	61	17				
100	55	71	61	17				
150	55	71	61	17				
200	54	70	59	15				
300	10,93	68	55	24				
400	83	69	57	27				
600	53	69	57	32				
800	12	74	66	47				
1150	9,46	78	73	64				
Stat. **75**. 9. March 1909. 5 p. m. 45° 37′ N, 7° 03′ W; depth > 4000 m.								
0	11,40	19,71	35,61	27,20				
25	26	70	59	20				
50	26	70	59	20				
100	27	70	59	20				
200	29	70	59	20				
300	10,94	69	57	25				
400	66	68	55	28				
600	30	72	62	40				
800	12	75	68	48				
1000	9,90	77	71	64				
1150	08	74	66	64				
Stat. **76**. 10. March 1909. 4 p. m. 47° 01′ N, 5° 48′ W; depth > 1200 m.								
0	10,78	19,66	35,52	27,23				
25	80	66	52	23				
50	80	66	52	23				
100	81	66	52	23				
200	78	63	46	19				
300	73	63	46	20				
400	73	63	46	20				
500	66	65	50	24				
600	46	64	48	26				
800	08	68	55	39				
975	9,58	70	59	50				
1150	28	68	55	52				

b) Summer Expedition 1910.

m	$t°$	Cl ‰	S ‰	σ_t	O'_2	O_2	$\frac{100\,O_2}{O'_2}$	p_H
Stat. **80.** 13. Jun. 1910. 7 p. m. 46° 17′ N, 7° 31 W.								
0	15,41	19,69	35,57	26,34	5,67	5,88	103,7	8,20
50	12,20	67	53	98	6,01	6,27	104,3	
100	11,01	65	50	27,18	15	5,65	91,9	8,08
200	10,68	66	52	25	19	65	91,3	8,08
400	48	66	52	28	22	19	83,5	8,06
800	07	78	73	54	26	4,34	69,4	8,04
1000	9,53	80	77	65	34	29	67,7	8,01
1200	8,78	77	71	73	44	49	69.7	7.98
1500	6,00	53	28	79	87	5,24	76,3	7,95
2000	3,83	39..	04	86	7,24	82·	80.4	7,95
Stat. **81.** 15. Jun. 1910. 6—9^{45} p. m. 41° 32′ N, 9° 32′ W.								
0	17,94	19,61	35,43	25,63	5,44	5,72	105,1	8,22
10	15,98	60	41	26,09	61	83	103,9	
25	15,33	61	43	23	68	38	94,7	
50	13,56	66	52	69	86	78	98,6	8,18
100	12,56	72	62	98	97	29	88,6	8,13
200	11,83	72	62	27,12	6,05	26	86,9	
400	01	69	57	24	15	4,85	78.9	8,04
600	00	79	75	38	15	39	71,4	
700	28	92	99	51	11	25	69,6	
800	25	94	36,02	54	11	17	68,3	8,01
1000	10,84	94	02	62	16	16	67,5	8,01
1200	9,89	$92_{,5}$	00	78	28	31	68,6	7,98
1500	6,97	65	35,50	83	69	97	74,3	7,95
2000	4,20	43	10	87	7,17	5,67	79,1	7,95
Stat. **84.** 16. Jun. 1910. 4^{30} p. m. 39°22′ N, 9° 23′ W; depth 30 m.								
0	17,00	19,74	35,66	26,04	5,52	6,50	117,8	8,22
5	14,14							
10	13,32	76	70	88	5,87	5,32	90,6	8,13
20	12,48	78	73	27,08	97	4,73	79,2	
28	48	78	73	08	97	76	79,7	8,08
Stat. **87.** 17. Jun. 1910. 1^{30}—3^{15} p. m. 37° 03′ N, 9° 15′ W; depth 1580 m.								
0	17,06	19,84	35,84	26,15	5,50	6,14	111,6	8,26
10	15,97	$83_{,5}$	83	41	60	28	112,2	
25	36	$83_{,5}$	83	55	66	5,73	101,2	8,20
50	14,48	89	93	82	75	15	89,6	
100	13,56	88	91	27,00	84	4,85	83,1	8,13
200	12,59	81	79	10	96	58	76,9	8,10
400	11,64	77	71	23	6,07			
600	12,12	97	36,08	41	00	4,30	71,7	8,06
800	01	20,06	24	56	00	18	69,7	8,04
1000	00	16	42	71	5,99	16	69,4	8,01
1200	11,59	17	44	81	6,04	22	69,9	8,01
1500	10,82	09	29	84	14	23	68,9	8,06
Stat. **89.** 18. Jun. 1910. 1 a. m. 36° 28′ N, 8° 22′ W; depth 1310 m.								
0	18,98	20,14	36,38	26,10	5,31	5 22	98,3	
25	18,60	15	40	22	35	25	98,1	
50	16,61	09	29	63	53	59	101,1	
100	15,09	03	18	88	68	19	91,4	
200	13,51	19,87	35,90	27,00	85	4,39	75,1	
400	11,49	72	62	18	6,09	53	74,4	
600	10,74	73	64	33	18	02	65,1	
700	61	78	73	44	20	3,88	62,6	
800	12,27	20,08	36,27	" 54	5,97	4,28	71,7	
1000	11,66	14	38	75	6,05	09	67,6	
1250	12,08	30	67	90	5,98	17	69,7	
Stat. **91.** 18. Jun. 1910. 3 p. m. 35° 53′ N, 7° 26′ W; depth 1225 m.								
0	19,08	20,19	36,47	26,15	5,30	5,28	99,6	8,24
50	17,11	11	33	53	48			8,18
100	15,69	10	31	84	61	5,29	94,3	8,13
200	14,13	19,95	04	97	78	4,79	82,9	8,08
300	12,96	83	35,82	27,06	91			
400	00	76	70	15	6,02	63	76.9	8,04
600	10,81	71	61	30	17	16	67,4	7,98
800	64	83	82	50	19	3,93	63,5	7,95
1000	10,30	19,94	36,02	27,71	6,22	4,00	64.3	7,98
1200	11,37	20,16	42	83	07	11	67,7	8,01
Stat. **92.** 19. Jun. 1910. 4^{45}—6^{00} a. m. 36° 16′ N, 6° 50′ W; depth 775 m.								
0	18,01	20,04	36,20	26,22	5,41	5,46	100,9	
10	17,98	04	20	22	41			
25	98	03	18	20	41	47	101,1	
50	16,17	11	33	75	56	68	102,1	
100	15,27	06	24	88	65	09	90,1	
200	13,73	19,91	35,97	27,01	83	4,76	81,7	
300	12,92	83	82	07	92	66	78,7	
400	35	80	77	14	98	60	76,9	
500	58	20,01	36,15	38	95	49	75.5	
600	19	26	60	81	97	28	71,7	
750	75	44	92	95	90	35	73,7	
Stat. **94.** 23. Jun. 1910. 1^{20} a. m. 36° 06′ N, 6° 02′ W; depth 65 m.								
0	18,48	19,97	36,08	25,99	5,37	5,36	99,8	
10	17,20	95	04	26,27	48	47	99,8	
25	16,08	97	08	57	58	27	94,5	
60	14,30	20,07	16	27,11	75	4,66	81,1	
Stat. **95.** 23. Jun. 1910. 4 a. m. 35° 57′ N, 6° 00′ W. depth 275 m.								
0	17,80	20,04	36,20	26,27	5,43	5,48	100,9	
10	78	00	13	21	43			
25	55	19,99	11	25	45	60	102,8	
50	15,60	20,03	18	77	63	40	95,9	
75	25	03	18	85	67			
100	14,95	19,96	06	82	69	04	88,6	
125	60	20,01	15	96	73			
150	07	08	27	27,17	77	4,74	82,2	
175	13,87	40	85	66	78			
200	57	72	37,43	28,17	79	34	75,0	
265	41	89	74	44	79	21	72,7	
Stat. **96.** 23. Jun. 1910. 11 a. m. 35° 48′ N, 5° 58′ W; depth 185 m.								
0	17,58	20,05	36,22	26,33	5,45	5,52	101,3	8,20
10	28	03	18	37	47	55	101,5	
25	15,86	04	20	72	60	26	93,9	
50	42	06	24	85	64	15	91,3	
100	14,87	02	17	92	71	4,99	87,4	8,20
150	54	19,99	11	94	74	84	84,3	
180	50	98	09	94	74	80	83,6	8,13
Stat. **97.** 23. Jun. 1910. 1 p. m. 35° 50′ N, 5° 59′ W; depth 598 m.								
0	18,36	20,01	36,15	26,08	5,38	5,47	101,7	8,24
100	15,10	05	22	91	68	13	90,3	8,20
160	14,30	19,96	06	96	76	4,84	84,0	8,15
175	40	99	11	98	75			
200	13,71	20,62	37,25	28,00	78	46	77,2	8,13
250	63	72	43	17	79	43	76,5	
300	48	84	65	40	79	29	74,1	8,10
400	49	83	63	39	79	29	74,1	8,08
575	22	21,08	38,08	75	80	13	71,2	8,07
175	14,24					86	84.7	
200	13,86	20,59	37,19	27,93				
200	90	47	36,98	75	77	54	78,7	
200	73	58	37,18	94	78	58	79,2	
Stat. **98.** 23. Jun. 1910. 5 p. m 35° 57′ N, 5° 35′ W; depth 700.								
0	17,96	19,95	36,04	26,09	5,41	5,48	101,3	8,24
25	16,24	99	11	56	57	48	98,4	8,22
50	15,79	97	08	64	61	36	95,6	
100	14,15	20,13	36	27,23	77	4,74	82,2	8,15
150	13,83	76	37,50	28,17	76	46	77,4	
200	76	82	61	28	76	40	76,4	8,13
225	46	98	90	56	78			
250	27	21,08	38,08	74	79	09	70,6	
300	01	22	33	98	81	01	69,0	8,09
500	12,93	24	37	29,03	82	3,98	68,4	8,07
700	95				81	4,02	69.2	8,07

Strong current from W.

m	$t°$	Cl ‰	S ‰	σ_t	O'_2	O_2	$\frac{100\,O_2}{O'_2}$	p_H
	Stat. **99.** 23. Jun. 1910. 9 p. m. 36°02′ N. 5°16′ W; depth 1150 m.							
0	16.80	20.07	36,26	26,54	5.51	5,24	95,1	
25	48	06	24	60	54	22	94.2	
50	15.00	22	53	27,17	67	4,98	87,8	
100	14.77	87	37,70	28,12	65	5,13	90.8	
125	13.55	96	86	51	77	4,29	74,4	
150	15	21,08	38.08	76	81	3,93	67,7	
200	12.97	20	30	97	81	85	66,3	
250	91	22	33	29,01	82	94	67,7	
300	89	23	35	03	82	97	68,2	
400	86	24	37	04	83	98	68,3	
500	84	24	37	05	83	4,11	70,5	
600	85	24	37	05	83	16	71,4	
900	83	24	37	05	83			
1000	83	24	37	05	83	02	69,0	
	Strong current from W.							
	Stat. **106.** 24. Jun. 1910. 11 p. m. 36°33′ N. 2°00′ W; depth c. 1100 m.							
0	20,92	20,24	36,56	25,74	5,16	5,13	99,4	
25	16,09	17	44	26,86	56	71	102,7	
50	14.86	36	78	27,40	68	10	89,8	
75	30	57	37,16	81	72	4,61	80.6	
100	13,61	94	83	28,47	77	29	74,4	
150	03	21,14	38,19	88	82	94	84,9	
200	12.89	16	22	93	82	90	84,2	
300	81	18,5	27	98	83	76	81,7	
400	85	21,5	31	29,01	83	48	76,8	
600	91	24	37	03	82	26	73,2	
800	92	24	37	03	82	22	72,5	
1000	89	24	37	04	82	25	73,0	
	Current from NE to a depth of about 200 m.							
	Stat. **107.** 25. Jun. 1910. 10[30] a. m. 3 p. m. 36°18′ N. 1°14′ W; depth c. 2250 m.							
0	21,26	20.44	36,92	25,91	5.12			8,24
10	19,60	47	98	26,39	24	5,15	98,3	
25	18,43	82	37,61	27,18	32			8,22
35	16,27							
50	14,20	84	65	28,21	72	47	95,6	8,13
75	13.28	21,07	38,06	72	79	4,75	82,1	
100	03	15	21	89	81	33	74,5	
150	12,92	20	30	98	82	33	74.4	8,09
200	96	22	33	29,00	81	15	71,4	8,09
300	99	25	39	04	81	03	69,4	
400	99	25	39	04	81	01	69,0	8,09
500	94	25	39	05	82	08	70,1	8,09
600	93	25	39	05	82	12	70,8	8,07
800	89	24,5	38	05	82	23	72,7	8,03
1000	88	24	37	04	82	26	73,2	8,07
1200	89	24,5	38	05				8,09
1500	93	23,5	36	02	82	36	74,9	8,12
2000	99	24	37	02	81	47	76,9	8,07
	Stat. **108.** 25. Jun. 1910. 8[30]–10 p. m. 36°03′ N. 0°27′ W.							
0	21,00	20,22	36,53	25,68	5,15	5,06	98,3	
10	18,91	21	51	26,22	32			
25	17,19	18	45	60	47	68	103,8	
50	15,38	38	82	27,30	62	62	100,0	
75	14,18	61	37,23	89	73			
100	13,76	98	90	28,49	75	4,43	77,1	
125	15	21,10	38,12	79	81			
150	01	14	19	88	82	26	73,2	
200	12,95	18	26	97	82	19	72,0	
300	13,00	24	37	29,01	81	01	69,0	
400	12,94	25	39	05	82	11	70,6	
600	90	25	39	05	82	15	71,3	
1000	88	24	37	04	82	30	73,9	
1500	93	23	35	02	82	41	75,8	
	Current from SW.							

m	$t°$	Cl ‰	S ‰	σ_t	O'_2	O_2	$\frac{100\,O_2}{O'_2}$	p_H
	Stat. **112.** 26. Jun. 1910. 9—12 p. m. 36°56′ N, 2°15′ E; depth c. 2600 m.							
0	21,96	20,59	37,19	25,91	5,05	4,92	97,4	
10	19,66	65	30	26,63	23	5,24	100,2	
17	17,57							
25	16,17	71	41	27,58	53	78	104,5	
35	14,97	81	59	28,00				
50	13.65	94	83	46	77	4,58	79,4	
75	17	21,10	38,12	79	80	61	79,5	
100	08	13	17	85	81	55	78,3	
150	12,93	19	28	96	82	60	79,0	
200	96	22	33	29,00	81	40	75,7	
250	13,02	22,5	34	00	81	31	74,2	
300	00	23,5	36	01	81	16	71,6	
400	12,95	25,5	39	04	82	31	74,1	
600	89	24	37	04	82	23	72,7	
800	86	23	35	03	83	18	71,7	
1000	86	23	35	03	83	33	74,3	
1200	89	23	35	03	82	34	74,6	
1500	93	23,5	36	03	82	50	77,3	
2000	99	23	35	01	81	64	79,9	
	Stat. **113.** 28. Jun. 1910. 2 a. m. 36°53′ N, 3°09′ E; depth 815 m.							
0	20,96	20,27	36,62	25,75	5,15	5,12	99,4	
25	16,39	36	78	27,05	53	62	101,6	
50	04	50	37,03	33	55	85	105,4	
75	14,78	43	36,91	50	78			
100	19	61	37,23	89	73	4,70	82,0	
125	13,67	91	77	28,42	77			
150	13	21,09	38,10	89	81	66	80,2	
175	09	18	26	92	80			
200	12	22	33	97	80	23	72,9	
250	23	29	46	29,04	79	01	69,3	
300	05	27	42	05	81	01	69,0	
400	12,88	26	40	07	82	14	71,1	
	Stat. **115.** 28. Jun. 1910. 8—11 p. m. 38°17′ N, 4°11′ E; depth 2800 m.							
0	21,92	20,65	37,30	26,00	5,06	4,96	98,0	
10	11	61	23	21	12			
25	17,97	59	19	98	37	5,47	101,9	
37	15,42	68	36	27,71	60	80	103,7	
50	14,72	77	52	28,00	66	81	102.7	
75	13,68	91	77	41	77	59	96.9	
100	23	21,04	38,01	69	81	4,99	85,9	
150	14	18	26	91	80	50	77,6	
200	21	23	35	96	79	34	74,9	
250	27	29	46	29,02	78	22	73,0	
300	23	28	44	02	79	21	72,7	
400	10	29	46	07	80	13	71,2	
500	12,97	27	42	07	81	16	71,6	
600	92	26	40	06	82	18	71,8	
1000	84	23,5	36	04	83	34	74,4	
1500	88	24	37	04	82	51	77.5	
2000	13,00	25	39	03	81	57	78,7	
2500	04	24	37	01	81	66	80,2	
	Stat. **116.** 29. Jun. 1910. 10 p. m. 39°27′ N, 5°26′ E; depth 2860 m.							
0	21,90	20,81	37,59	26,24	5,05	4,83	95,6	
1	90					80		
2	81					85		
3	69					84		
4	33					91		
5	20,78					91		
7,	53					90		
10	38	78	54	61	17	92	95,2	
15	26					94		
20	14					94	95,4	
25	18,48	80	57	27,14	32	5,22	98,1	
35	16,70				47	50	100,6	
50	15,22	90	75	28.07	61	57	99,3	
75	14,00	98	90	44	73	56	97,0	

m	$t°$	Cl ‰	S ‰	σ_t	O'_2	O_2	$\frac{100\ O_2}{O'_2}$	p_H
100	13,30	21,05	38,03	28,69	5,80	4,84	83,4	
200	16	23	35	97	79	55	78,6	
300	25	29	46	29,04	79	22	72,9	
400	10	28	44	05	80	12	71,0	
600	12,97	25	39	04	81	15	71,4	
800	91	24	37	03	82	22	72,5	
1000	86	24	37	04	83	30	73,8	
1500	92	23	35	02	82	37	75,1	
2400	13,02	24,5	38	02	81	57	78,7	

Stat. **118**. 30. Jun. 1910. 7—10[40] p. m. 41°00′ N, 6°43′ E; depth > 2700 m.

0	20,73	20,85	37,66	26,62	5,14	4,92	95,7	8,26
10	56	84	65	65	15	5,07	98,4	
25	17,48	87	70	27,48	41	57	102,9	8,24
35	15.84				55	76	103.8	
50	14,66	94	83	28,24	66	75	101,6	8,24
75	13,38	99	92	59	79	15	88,9	8,22
85	32							
100	42	21,09	38,10	72	78	25	90,8	8,19
125	27	15	21	83	80	4,93	85,0	
150	20	21	31	93	79	48	77,4	8,14
175	31				78	42	76,5	
200	57	31	49	29,00	75	18	72,7	8,14
250	40				77	14	71,7	
300	27	29	46	04	78	22	73,1	8,12
400	16	29	46	06	79	05	69,9	8,09
600	12,98	27	42	07	81	08	70,2	8,07
1000	90	24	37	03	82	30	73,9	8,07
1500	94	24	37	03	82	41	75.8	
2000	13,01	25	39	03	81	55	78,3	8,07
2500	07	25	39	02	80	59	79,1	8,07

Stat. **120**. 1. Jul. 1910. 4[45]—8 p. m. 42°31′ N, 7°41′ E; depth c. 2700 m.

0	18,36	21,19	38,28	27,71	5,31			
25	15,02	17	24	28,49	61	6,01	107,1	
50	13,42	20	30	88	77	5,40	93,6	
75	07	22	33	98	80	4,72	81,4	
100	10	25	39	29,01	80	63	79,8	
125	16							
150	17	27	42	03	79	40	76,0	
175	11							
200	12	29	46	07	80	26	73,4	
250	12	29	46	07	80	14	71,4	
300	05	27,5	43	05	81	15	71,4	
400	12,94	25	39	05	82	31	74,1	
600	88	24	37	04	82	31	74,1	
1000	88	24	37	01	82	47	76,8	
1500	96	24	37	02	81	56	78,5	
2000	13,01	24,5	38	02	81	54	78,1	
2500	06	24	37	00	80	58	79,0	

Stat. **122**. 2. Jul. 1910. 11[30] a. m.—4 p. m. 43°50′ N, 8°34′ E; depth 1285 m.

0	19,46	21,20	38,30	27,45	5,21	5,27	101,2	8.29
10	17,77	17	24	83	36	38	100,4	8,25
15	14,22				70	97	104,7	
25	13,58	05	03	28,63	77	69	98,6	
50	22	11	13	79	80	03	86,7	
75	22	19	28	90	79	06	87,4	8,23
100	20	23	35	96	79	4,71	81,3	8,21
125	22				79	50	77,7	
150	35	29	46	29,02	78	18	72,3	
200	54	34	55	04	76	16	72,2	8,21
250	36	31	49	04	77	27	74,0	
300	29	30	48	04	78	19	72,5	
400	23	29	46	04	79	18	72,2	8,19
500	05	26	40	03	80	20	72,4	8,19
600	12,98	25	39	04	81	27	73,5	8,17
800	92	24	37	03	82	35	74,8	8,17
1000	91	25	39	05	82	47	76,8	8,12
1250	93	24	37	03	82	63	79,6	8,07
1300	94	24	37	03				

m	$t°$	Cl ‰	S ‰	σ_t	O'_2	O_2	$\frac{100\ O_2}{O'_2}$	p_H

Stat. **123**. 2. Jul. 1910. 11 p. m. 44°14′ N, 8°55′ E; depth c. 700 m.

0	20,26	20,98	37,90	26,91	5,16	5,04	97,7	
25	16,72	21,08	38,08	27,94	45	66	103,9	
50	14,20	01	37,95	28,44	71	71	100,0	
75	13,97	11	38,13	63	72	56	97,2	
100	50	13	17	76	77	19	89,9	
150	38	15	21	81	78	15	89,1	
200	32	19	28	89	78	4,77	82,5	
300	53	32	51	29,02	76	33	75,2	
400	46	31	49	03	76	21	73,1	
500	34	30	48	03	78	27	73,9	
600	21	29	46	05	79	20	72,5	

Stat. **125**. 9. Jul. 1910. 8—9[30] p. m. 43°54′ N, 9°13′ E; depth 1082 m.

0	19,06	21,23	38,35	27,59	5,25	5,25	100,0	8,23
10	17,96	19	28	82	34	59	104,7	
15	66							
20	15,20							
25	14,60	02	37,97	28,36	66			
50	13,42	03	99	64	79	33	92,1	8,19
75	22				80	02	86,6	
100	26	15	38,21	84	79	4,80	82,9	
150	32				78	51	78,0	
200	46	26	40	95	76	35	75,5	8,17
300	54	32	51	29,02	76	23	73,4	
400	21	29	46	05	79	30	74,2	8,14
600	15	27	42	03	79	18	72,2	8,12
800	01	26	40	04	81	26	73,3	8,12
1050	12,91	24	37	03	82	49	77,1	8,09

Stat. **126**. 10. Jul. 1910. 1[30]—3[30] p. m. 42°43′ N, 9°50′ E; depth 588 m.

0	21,66	21,01	37,95	26,58	5,05	4,96	98,2	8,25
10	20,62	00	94	85	13	5,05	98,4	
25	19,50	06	38,04	27,25	21	14	98,7	
35	18,06							
40	17,16				42	56	102,5	
50	15,23	05	03	28,27	60	73	102,3	8,23
75	14,30	08	08	52	69	64	99,1	
100	13,93	09	10	62	73	51	96,2	8,21
150	54	16	22	80	76	08	88,2	
175	50				76	00	86,8	
200	46	22	33	90	76	4,94	85,8	8,19
300	51	32	51	29,02	76	50	78,1	
400	50	33	53	03	76	46	77,4	8,17
500	48	33	53	04	76	27	74,1	8,14
580	43	33	53	05	77	12	71,4	8,12

Stat. **128**. 11. Jul. 1910. 2[30]—5[15] p. m. 41°01′ N, 10°53′ E; depth 1630 m.

0	20,27	21,15	38,21	26,88	5,15	5,11	99,2	8,23
10	18,46	18	26	27,68	30	30	100,0	
25	17,52	17	24	89	38	40	100,2	
50	14.88	15	21	28,48	62	83	103,7	8,23
75	02	20	30	75	71	65	98,9	
100	13,57	22	33	88	75	39	93,7	8,21
150	50	28	44	97	76	4,77	82,8	
200	59	32	51	29,01	75	58	79,7	8,19
300	74	38	62	06	73	31	75,2	
400	73	38,5	63	07	73	26	74,3	8,19
500	64	38	62	08	74	20	73,2	8,17
600	59	37	60	07	74	15	72,3	8,17
800	43	35	57	08	76	11	71,4	
1000	32	32	51	06	78	10	70,9	8,14
1200	24	30	48	05	79	10	70,8	8,12
1500	19	29	46	05	79	08	70,5	8,07

Stat. **129**. 12. Jul. 1910. 6[00] a. m. 40°05′ N, 11°31′ E; depth 3420 m.

0	21,76	21,01	37,95	26,55	5,04			8,23
10	16	20,98	90	67	09	4,76	98,5	

m	$t°$	Cl ‰	S ‰	σ_t	O'_2	O_2	$\frac{100\,O_2}{O'_2}$	p_H
25	19,68	20,97	37,88	27,07	5,21	5,02	96,4	8,23
35	16,30							
50	15,18	21,08	38,08	28,32	59	64	100,9	8,23
75	14,24	12	15	59	69	54	97,4	
100	13,75	16	22	75	74	04	87,8	8,21
150	86	32	51	95	72	4,43	77,4	
200	97	34	55	95	71	34	76,0	8,19
300	82	36	58	29,01	72	32	75,5	
400	77	38	62	05	72	29	75,0	8,19
500	75	39	64	07	72	22	73,8	
600	70	37	60	05	73	19	73,1	
800	56	36	58	07	74	17	72,6	8,17
1000	42	33	53	05	77	14	71,7	8,14
1200	32	31	49	05	78	12	71,3	8,14
1500	21	29	46	05	79	14	71,5	8,12
2000	18	27	42	03	79	15	71,7	8,09
2500	20	26	40	00	79	17	72,0	8,07
3200	29	27	42	00	78	21	72,8	8,07

Stat. **131.** 13. Jul. 1910. 2 p. m. 38° 36′ N, 11° 00′ E; depth 921 m.

0	21,48	21,02	37,97	26,63	5,06	5,05	99,8	8,27
10	20,42	03	99	95	15	4,66	90,5	
25	19,72	01	95	27,12	19	5,15	99,2	8,25
35	15,90	09	38,10	28,18	52	84	105,8	
50	14,58	05	03	42	66	80	102,5	
75	13,41	06	04	68	78	18	89,6	
100	40	13	17	78	78	4,99	86,3	8,21
125	57	22	33	87	75	69	81,6	
150	74	28	44	91	74	47	77,9	8,19
175	74				74	28	74,6	
200	74	32	51	97	74	19	73,0	
300	72	36	58	29,04	73	12	71,9	8,19
400	58	35	57	05	74	15	72,3	
500	47	33	53	04	76	18	72,6	
600	30	32	51	07	78	15	71,8	
700	20	30	48	06	79	12	71,2	8,12
800	11	29	46	07	80	15	71,6	8,09
900	05	28	44	06	81	19	72,1	8,09

Stat. **132.** 14. Jul. 1910, 6—8^{15} a. m. 38° 57′ N, 9° 47′ E; depth 1650 m.

0	20,46	21,04	38,01	26,95	5,14	5,08	98,8	
10	19,00	09	10	27,41	25	21	99,2	
15	18,15				33	37	100,8	
20	15,82				53	72	103,4	
25	25	12	15	28,36	59	81	103,9	
50	14,16	14	19	65	70	70	100,0	
75	13,60	17	24	79	75	30	92,2	
100	50	21	31	87	76	4,90	85,1	
125	40	24	37	93	77	89	84,8	
150	51	27	42	96	76	70	81,6	
200	61	30	48	97	75	56	79,3	
300	76	36	58	29,03	72	28	74,8	
400	76	36	58	03	72	20	73,4	
600	55	34	55	04	75	21	73,2	
800	36	32	51	06	77	12	71,4	
1000	24	30	48	05	79	11	71,0	
1200	18	28,$_5$	45	04	79	11	71,0	
1500	16	28	44	04	79	13	71,3	

Stat. **133.** 14. Jul. 1910. 6—8 p. m. 38° 18′ N. 9° 59′ E; depth 602 m.

0	21,82	21,04	38,01	26,58	5,03	4,95	98,4	8,27
10	20,72	02	37,97	85	12	5,00	97,7	8,27
25	19,66	10	38,12	27,26	20	13	98,7	
35	15,46				56	70	102,5	
50	14,48	00	37,94	28,36	68	70	100,4	8,21
75	13,41	07	38,06	70	78	09	88,1	
100	52	18	26	83	76	4,95	85,9	8,21
150	68	28	44	93	74	35	75,8	
200	82	34	55	99	73	19	73,1	8,17
250	59	35	57	29,04	75	07	70,8	
300	46	32	51	03	76	04	70,1	8,12
400	33	31	49	05	78	08	69,7	8,09
500	13,18	21,28	38,44	29,03	5,79	4,06	70,1	8,09
590	12,99	27	42	08	81	14	71,3	8,09

Current from SSW, 35 cm/sec. at the surface.

Stat. **134.** 15. Jul. 1910. 9—10^{30} a. m. 37° 37′ N. 10° 17′ E: depth 395 m.

0	22,60	20,55	37,12	25,68	5,00	4,93	98,6	8,27
10	21,67	56	14	95	08	98	98,0	8,25
25	20,40	72	43	26,53	17	5,11	98,8	
35	17,88				38	61	104,3	
50	15,41	41	36,87	27,29	62	71	101.6	8,23
75	14,31	67	37,34	94	72	20	90,9	
100	13,92	83	63	28,26	75	30	92,2	8,21
125	70	94	83	45	76	21	90,5	
150	50	21,14	38,19	78	77	4,84	83,9	8,21
175	58	24	37	89	75	39	76,3	
200	68	31	49	97	74	24	73,9	8,14
250	68	35	57	29,02	74	01	69,9	
300	50	35	57	06	76	3,87	67,2	8,12
385	15	31	49	09	79	4,01	69,3	8.07

Stat. **135.** 15. Jul. 1910. 11^{30} p. m. 37° 17′ N, 10° 28′ E; depth 174 m.

0	22,92	20,55	37,12	25,59	4,98	4,82	96,8
10	08	53	09	79	5,04	85	96,2
25	20,92	55	12	26,16	14	5,06	98,4
50	17,21	60	21	27,18	44	43	99,8
75	15,07	65	30	74	64	47	97,0
100	14,42	80	57	28,10	69	40	94,9
125	13,80	97	88	47	75	20	90,4
150	54	21,12	38,15	74	77	4,58	79,4
170	58	22	31	85	75	41	76,7

Stat. **137.** 19. Jul. 1910 10 a. m. 37° 19′ N, 10° 56′ E; depth 190 m.

0	22,76	20,63	37,27	25,73	4,99	4,89	98,0
10	00	62	25	94	5,05	97	98,4
25	19,90	90	75	26,91	18	5,19	100,2
35	38						
40	18,60	85	66	27,19	31	39	101,5
45	16,56						
50	15,48	60	21	58	60	80	103,6
75	14,44	78	54	28,07	69	53	97,2
100	06	91	77	33	72	33	93,2
125	13,83	98	90	47	82	31	92,4
150	69	21,08	38,08	65	75	4,94	85,9
180	62	15	21	77	75	74	82,4

Stat. **138.** 19. Jul. 1910. 4^{45} p. m. 37° 37′ N, 11° 25′ E; depth 788 m.

0	23,50	20,80	37,57	25,76	4,92	4,87	99,0
10	22,43	76	50	26,02	99	94	99,0
25	19,98	97	88	99	5,18	5,24	101,1
35	18,42						
40	16,48				48	74	104,7
56	15,62	76	50	27,78	58	77	103,4
75	14,82	90	75	28,15	65	72	101,2
100	43	97	88	34	68	59	98,4
125	27	21,05	38,03	49	69	28	92,8
150	13,79	15	21	72	71	4,96	86,8
175	71	20	30	82	75	62	80,4
200	81	28	44	90	72	38	76,6
360	90	38	62	29,03	70	28	75,1
400	84	41	68	08	70	26	74,7
500	82	41	68	08	71	22	73,9
600	82	40,$_5$	67	08	71	21	73,7
700	82	41	68	08	71	22	73,9
775	83	41	68	08	71	13	72,3

Stat. **139.** 20. Jul. 1910. 6—8 a. m. 37° 57′ N. 11° 54′ E; depth c. 700 m.

0	21,96	20,70	37,39	26,07	5,06	4,91	97,0
10	26	66	32	21	11	89	95,7
25	17,84	60	21	27,02	39	5,33	98,9
50	15,74	63	27	56	57	48	98,4

m	$t°$	Cl ‰	S ‰	σ_t	O'_2	O_2	$\frac{100\ O_2}{O'_2}$	p_H
75	14,81	20,83	37,63	28,06	5,65	5,40	95,5	
100	45	21,00	94	37	69	10	89,7	
150	17	31	38,49	87	68	4,60	81,0	
175	09	35	57	94	69	43	77,9	
200	11	40	66	29,01	68	52	79,6	
300	13,97	40	66	04	69	37	76,8	
400	87	41	68	07	71	32	75,7	
500	84	41	68	08	72	22	73,8	
650	87	41	68	07	71	20	73,6	
700	86							

Current from W 42 cm/sec.

Stat. **141**. 20. Jul. 1910. 11 p. m. 36°42′ N, 13°34′ E; depth c. 500 m.

0	23,76	20,79	37,56	25,67	4,91	4,77	97,2
25	16,47	81	59	27,64	5,49	5,57	101,5
50	14,88	21,01	95	28,30	63	57	98,9
100	46	36	38,58	87	65	4,75	84,1
200	09	43	71	29,06	68	43	78,0
300	13,91	43	71	09	70	32	75,8
475	83	42,5	70	10	71	27	74,8

Stat. **142**. 22. Jul. 1910. 5 a. m. 35°44′ N, 15°07′ E; depth 98 m.

0	24,05	20,78	37,54	25,57	4,88	4,75	97,3
10	21,58	75	48	26,24	5,07	95	97,6
25	19,62	71	41	72	24	5,33	101,8
35	17,48						
40	16,84	72	43	27,44	47	57	101,9
50	00	76	50	68	54	63	101,6
75	14,98	87	70	28,07	63	59	99,3
95	92	90	75	13	64	49	97,3

Stat. **143**. 22. Jul. 1910. 5[30]—8[30] p. m. 35°18′ N, 16°25′ E; depth 1842 m.

0	25,26	21,04	38,01	25,56	4,78	4,62	96,7	8,27
10	23,08	06	04	26,23	94	84	97,9	8,25
17	20,62	20,94	37,83	77	5,14	5,16	100,4	
25	17,28	90	75	27,58	42	53	102,1	8,23
50	16,17	21,08	38,08	28,09	50	60	101,8	8,23
75	15,00	15	21	46	61	56	99,1	
100	14,69	26	40	67	63	18	92,0	8,21
150	36	43	71	99	65	4,71	83,3	
162	32							
175	33	45	75	29,03	67	72	83.2	
200	20	45	75	06	67	63	81,6	8.17
300	13,91	43	71	09	69	52	79,4	
400	71	41,5	68	11	71	48	78,4	8,14
600	64	40	66	11	73	34	75,8	8,12
800	60	40	66	12	73	30	75,0	
1000	56	39,5	65	12	74	23	73,7	8,12
1250	56	39	64	11	74	27	74,4	
1500	56	39	64	11	74	26	74,2	8,09
1800	58	39	64	10	74	25	74.1	8,09

Stat. **144**. 23. Jul. 1910. 7—12 p. m. 34°31′ N, 18°40′ E; depth 3340 m.

0	26,05	21,31	38,49	25,68	4,70	4,64	98,7
10	25,30	31	49	90	76	51	94,7
25	22,50	11	13	26,47	98	92	98,8
35	20,60	16	22	27,08			
50	17,28	18	26	28,00	5,40	5,53	102,5
75	16,10	19	28	26	50	57	101,3
100	15,40	23	35	48	56	43	97,6
150	14,66	39	64	87	63	4,89	86,9
200	41	47	78	29,04	65	65	82,3
300	15	48	80	11	67	61	81,3
400	13,96	46	77	12	69	35	76.5
600	76	43,5	72	13	72	16	72,8
1000	58	40	66	12	73	05	70,7
1500	55	39	64	11	73	02	70,2
2000	56	39	64	11	75	19	72,9
2500	60	39	64	10	74	26	74,2
3200	69	39	64	08	72	35	76,1

Current from NW.

m	$t°$	Cl ‰	S ‰	σ_t	O'_2	O_2	$\frac{100\ O_2}{O'_2}$	p_H
Stat. **145**. 25. Jul. 1910. 7—9[40] a. m. 32°38′ N, 19°02′ E; depth 1925 m.								
0	25,36	21,32	38,51	25,89	4,77	4,58	96,1	8,27
10	36	29	46	85	76	59	96,4	8,29
25	23,40	23	35	26,38	91	86	98,9	
35	19,76	18	26	27,34	5,20	5,32	102,4	
50	17,76	17	24	84	36	56	103,7	8,27
75	16,00	15	21	28,23	52	61	101.7	
100	15,38	19	28	43	56	48	98,6	8,23
150	14,87	35	57	76	61	24	93,4	
200	49	45	75	99	64	4,73	83,8	8,23
300	19	47	78	29,09	67	54	80,1	
400	05	46	77	10	68	41	77,7	8,21
600	13,78	43	71	12	71	12	72,2	8,17
1000	58	41	68	13	73	3,94	68,8	8,14
1500	52	39	64	11	74	4,08	71,1	8,12
1800	51	38,5	63	11	76	15	72,1	8,12
Stat. **147**. 25. Jul. 1910. 8—10 p. m. 31°35′ N, 19°02′ E; depth 993 m.								
0	25,20	21,15	38,21	25,73	4,78	4,62	96,6	
10	12	12	15	72	79	61	96,3	
25	23,69	06	04	26,06	90	81	98,1	
35	20,08	02	37,97	27,02	5,17	5,34	103,3	
50	17,42	01	95	70	40	58	103,3	
75	16,31	05	38,03	28,02	50	54	101,0	
100	15,70	09	10	22	54	50	99,2	
125	48	15	21	35	57	34	95,9	
150	12	20	30	51	59	28	94,4	
200	14,64	37	60	84	63	4,87	86,5	
300	15	46	77	29,08	67	41	77,8	
400	13,85	44	73	12	70	19	73,5	
600	62	40	66	11	73	08	71,2	
800	50	39	64	12	74	09	71,3	
925	44				74	10	71,4	
950	43	39	64	13	77	14	71,7	
Stat. **148**. 26. Jul. 1910. 9—10[30] a. m. 30°45′ N, 19°02 E; depth 290 m.								
0	24,70	21,25	38,39	26,02	4,83	4,71	97.8	
10	59	24	37	03	82	62	95,9	
25	53	23	35	04	83	61	95,4	
35	23,44	21	31	34	92	80	97,5	
50	18.66	16	22	27,60	5,28	5.46	103.4	
75	16,76	15	21	28,05	28	57	102.3	
100	15,92	13	17	22	52	48	99,2	
150	20	16	22	43	59	29	94,6	
200	14,64	34	55	80	64	4,88	86,6	
275	11	45	75	29,08	68	34	76,4	
Stat. **150**. 26. Jul. 1910. 2[30] p. m. 30°23′ N, 19°02′ E: depth 35 m.								
0	25,57	21,21	38,31	25,68	4,74	4,64	97,8	8.31
10	52	20	30	70	75	65	97,9	
20	40	20	30	73	76	67	98,0	8,27
32	02	19	28	84	79	71	98.3	8,25
Stat. **152**. 28. Jul. 1910. 4—7 a. m. 33°11′ N, 21°44′ E; depth c. 2100 m.								
0	24,34	21,38	38,62	26,30	4,83	4,51	93,3	
10	35	36	58	27	84	49	92,7	
25	30	36	58	29	85	48	92,4	
35	21,45	29	46	27,01	5,06	98	98,4	
40	20,60							
50	19,20	27	42	61	23	5,17	98,9	
75	16,97	23	35	28,11	42	57	102,7	
100	15,99	24	37	36	52	52	100,0	
150	11	36	58	73	60	20	92,9	
175	01	43	71	85	59	01	89,7	
200	14,99	51	86	96	58	4,89	87,7	
250	51	50	84	29,06	63	63	82,2	
300	30	48,5	81	08	65	49	79,4	
400	13,98	46	77	12	69	31	75,8	
600	67	42	69	13	71	12	72,1	

m	$t°$	Cl ‰	S ‰	σ_t	O'_2	O_2	$\frac{100\ O_2}{O'_2}$	p_H
800	13,52	21,39,5	38,65	29,12	5,73	4,12	71.9	
1000	50	40	66	14	73	12	71,9	
1250	49	39.5	65	13	74	14	72,1	
1500	50	39	64	12	74	16	72.5	
2000	52	39	64	11	74	26	74,2	

Stat. **154.** 29. Jul. 1910. 6 a. m. 32°10′ N, 24°46′ E; depth 300 m.

0	24 60	21,41	38,68	26,27	4,82	4,43	92,0	8,25
10	60	40	66	26	81	40	91,5	
25	55	41	68	28	82	38	90,9	
50	23,69	37	60	48	90	52	92,3	8,29
65	21,37	29	46	27,04	5,07	87	96,1	
75	18,38	22	33	75	30	5,21	98,3	
100	16,69	38	62	28,38	43	00	92,1	8,25
150	15,80	48	80	73	50	4,80	87,3	
200	29	53	89	92	55	54	81,9	8,23
280	14,33	48	80	29,07	65	15	73.5	8,19

Stat. **156.** 29. Jul. 1910. 8—12 p. m. 32°24′ N, 26°51′ E; depth c. 3200 m.

0	25,47	21,61	39,04	26,26	4,74	4,48	94,6
10	46	60	02	25	73	31	91,1
25	22,60	52	38,87	27,01	95	78	96,6
35	19,95	36	58	53	5,17	5,23	101,2
50	17,25	30	48	28,14	39	30	98,3
75	16,20	33	53	42	48	30	96,8
100	15,70	35	57	57	52	33	96,6
150	31	53	89	92	54	00	90,2
200	11	54	91	98	57	4,78	85,8
300	14,45	51	86	29,09	64	48	79,4
400	19	49	82	12	66	32	76,3
600	13,86	44	73	12	70	05	71,1
1000	64	41	68	12	73	3,92	68,4
1500	61	40	66	12	73	84	67,0
2000	62	39	64	09	73	87	67,5
2500	69	40	66	10	71	88	67,9
3000	76	40	66	08	70	4,02	70,5

Stat. **158.** 31. Jul. 1910. 5—7^{30} a. m. 34°23′ N, 27°57′ E; depth $\dot{2000}$ m.

0	24,08	21,69	39,18	26,80	4,84	4,51	93,2
10	09	68	16	79	84	55	94,0
25	10	69	18	80	84	52	93,4
35	19,30	59	00	28,02	5,20	5,51	105,9
50	17,21	57	38,96	53	37	55	103,3
75	15,70	56	95	87	51	21	94,6
100	17	55	93	98	56	4,78	86,0
150	14,72	54	91	29,07	61	67	83,2
175	60	53	89	08	62	63	82,4
200	59	53	89	08	62	62	82,2
300	29	49	82	09	65	55	80,6
400	05	47	78	12	67	23	74,6
600	13,81	42	69	10	72	06	71,0
1000	61	39	64	10	73	3,87	67,5
2000	63	38,5	63	09	73	82	66,7

Stat. **160.** 1. Aug. 1910. 6^{30}—10^{30} a. m. 35°59′ N, 28°14′ E; depth 2980 m.

0	26,28	21,71	39,22	26,15	4,67	4,36	93,4
10	05	68	16	19	69	38	93,4
25	21,70	63	07	27,42	5,01	5,06	100,9
50	17,25	57	38,96	28.52	36	52	102,9
75	15,70	55	93	86	53	30	95,9
100	02	54	91	29,00	58	4,97	89,1
150	14,57	54	91	10	63	48	79,6
175	38	51	86	10	64	39	77,8
187	36				64	39	77,8
200	36	51	86	11	63	40	78,1
300	13	50	84	14	68	33	76,2
400	13,96	46	77	12	70	22	74,1
600	76	44,5	74	15	71	03	70,6
800	66	43	71	14	72	3,98	69,6
1000	60	41	68	13	73	89	67,9
1250	59	41	68	13	73	84	67,0

m	$t°$	Cl ‰	S ‰	σ_t	O'_2	O_2	$\frac{100\ O_2}{O'_2}$	p_H
1500	13,60	21,40,5	38,67	29,12	5,73	3,82	66,7	
2000	61	41	68	13	73	86	67,4	
2500	71	40	66	09	72	87	67,7	
2975	78	40	66	08	70	4,05	71,0	

Stat. **163.** 2. Aug. 1910. 9—11 p. m. 37°52′ N, 26°22′ E; depth 1170 m.

0	22,60	21,66	39,13	27,20	4,95	4,83	97,5	
10	45	65	11	23	96	80	96,8	
25	18,75	60	02	28,18	5,24	5,39	102,9	
50	17,36	61	04	54	36	42	101,1	
75	16,60	62	05	74	42	33	98,4	
100	28	61	04	79	44	21	95,7	
150	15,88	60	02	88	49	09	92,7	
200	26	57	38,96	98	56	14	92,5	
250	14,61	52	87	22,06	62	23	93,0	
300	31	50	84	10	66	21	92,1	
400	13,53	49,5	83	26	74	22	91,0	
600	35	49	82	30	76	20	90,3	
800	34	49	82	30	75	15	89,5	
1000	36	50	84	30	75	15	89.5	
1140	39	50	84	30	75	08	88,4	

Stat. **170.** 6. Aug. 1910. 12—3 p. m. 40°46′ N, 28°57′ E; depth 1235 m.

0	24,8	11,90	21,51	13,29	5,29	5,25	99,2	8,35
10	21,35	12,01	71	14,38	55	85	105,4	8,33
15	17,15	13,34	24,11	17,19	89	6,26	106,3	8,26
20	15,62	14,91	26,94	19,68	96	42	107,7	8,22
22½	14,95		30,5	c.22.54	89	14	104,2	
25	15,27	19,17	34,63	25,65	70	5,28	92,6	8,13
30	15,90	20,74	37,47	27,69	55	4,31	77,6	
35	90	21,04	38,01	28,10	53	10	74,2	
50	35	20	30	46	58	3,08	55,2	8,07
75	14,90	26	40	63	61	1,92	34,2	
100	59	30	48	76	64	86	33,0	8.03
150	33	30	48	82	66	75	30,9	
200	22	29	46	83	67	56	27,5	8,03
300	14	30	48	86	68	55	27,3	8,09
400	13	29	46	85	69	66	29,2	
600	13	29,5	47	86	68	93	34,0	8,09
800	15	30	48	86	70	2,04	35,8	8,09
1000	17	29	46	84	68	09	36.8	8,09
1200	20	29	46	84	67	06	36,3	8,03

Stat. **171.** 10. Aug. 1910. 4 p. m. 41°32′ N, 29°24′ E; depth 60 m.

0	23,2	9.95	17,99	11,08	5,54	4,61	83,2	8,35
10	21,5	99	18,06	58	67	88	86,1	8,35
17	4		0	56	67	5,13	90,4	
20	17,45	10,11	28	12,68	6,07	49	90,4	
25	14,07	24	51	13.53	45	99	92,8	8,31
33	11,47	12,45	22,50	17.04	62	66	85,5	
40	13,85	15,91	28,75	21,42	08	4,98	81,9	
45	15,0	19,45	35,14	26,10	5,72	3,94	68,9	
50	38	49	21	08	67	70	65,2	8,20
58	54	20,30	36,67	27,15	62	58	63,7	

Stat. **172.** 10. Aug. 1910. 10^{30}—12 p. m 41°32′ N, 29°24′ E; depth 1090 m.

0	24,1	9,73	17,59	10,06	5,47	5,14	94,0	8,34
10	1	73	59	56	44	14	94,4	8,25
15	0		5		46	12	93.7	
17½	23.65		4		50	28	96,0	
20	16,87		18,2		6,13	6,96	113,5	
25	12,73	10,08	22	13.54	63	7,40	111,6	8,19
35	10,26	09	24	92	98	29	104,4	
50	8,22	12	30	22	7,31	6,71	91,8	8,15
75	7,44	34	69	14,62	42	+5,51	74,3	8,03
85	31	52	19,02	88	42	+4,44	59,8	7,99
100	61	87	65	15,33	35	+2,33	31,7	7,86
150	8,31	11,48	20,75	16,12	17	+0,17	2,4	
200	54	78	21,29	51		÷0,90		7,67
300	68	12,01	71	82		÷2,34		7,55
400	72	12	91	97		÷4,17		7,53

m	$t°$	Cl ‰	S ‰	σ_t	O'_2	O_2	$\frac{100\,O_2}{O'_2}$	p_H
600	8,76	12,26	22,16	17,16		÷4,96		(7,26)
800	80	29	21	19		÷6,06		(7,26)
1000	85	32	27	24		÷6,04		(7,26)

Stat. **173**. 11. Aug. 1910. 6 a. m. 41° 17′ N, 29° 11′ E; depth 65 m.

0	24,25	9,78	17,68	10,57				
12½	24,0							
18	22,5							
21	15,2							
25	11,27	10,09	18,24	78				
40	8,55							
60	15,32	20,20	36,49	27,07				

Stat. **174**. 11. Aug. 1919. 1 p. m. 40° 54′ N, 28° 53′ E; depth 120 m.

0	23,8		21,7	13,77				
10	21,6		9	14,50				
15	18,7		24,5	17,12				
20	15,2		29,6	21,80				
25	16,0		37,1	27,38				
30	2		37,6	71				
50	15,4		38,4	28,51				

Stat. **175**. 11. Aug. 1910. 8 p. m. 40° 48′ N, 27° 59′ E; depth 1103 m.

0	24,9	12,01	21,71	13,42	5,28	5,07	96,1	8,23
10	5	05	78	59	31	4,59	86,5	8,20
15	20,2		24.0	16.5	62	5.43	96,6	
18	17.0		25,8	18,5				
20	15.55	15,03	27,16	19,87	5.95	80	97,5	8,13
22½	7		34.0	25,07				
25	16,3	20,64	37.29	27,45	5.52	4,86	88,1	8,09
30	6		38,3	28,16	46	15	76.0	
50	15.55	27	42	50	55	3,52	63,4	
100	14,63	33	53	79	64	2,19	38,8	8,03
300	17	32	51	88	67	1,81	31,9	8,03
600	09	30,5	49	88	69	2,32	40,8	8,05
1050	07	30	48	87	70	40	42,1	8,05

Stat. **177**. 12. Aug. 1910. 8[30] a. m. 40° 32′ N, 27° 03′ E; depth 55 m.

0	25.0	12,25	22,14	13,71	5,26	5,01	95,3
10	24,95	24	12	70	26	4,98	94,6
15	5	52	63	14,22	30	5,11	96,5
20	16,4	14.50	26,20	18,95	89	6,50	110,4
25	03	18,46	33,35	24,50	68	5,85	103,0
30	58	20,89	37,74	27,73	48	00	91,3
50	45	21,46	38,77	28,55	45	4,28	78,6

Stat. **178**. 12. Aug. 1910. 1 p. m. 40° 16′ N, 26° 32′ E; depth c. 70 m.

0	25,2		22,2	13,7			
10	25,1		1	6			
15	21,8		24,5	16,4			
18	16,75		30,4	22,0			
20	16,9		34,5	25,1	5,56	5,55	99,8
22	17,1		36,4	27,0			
25	1		38.0	8			
40	16,8		8	28,5			
70	4		8	6			

Stat. **178a**. 12. Aug. 1910. 5—11 p. m. 40° 08′ N, 26° 24′ E; depth 60 m.

0	25,0		22,4				
5	0						
10	24,8		22,5				
11	75		5				
12	65		6				
13	45		8				
14	4		9				
15	4		23,0				
16	4		22,9				
17	21,2		29,1				
18	18,25		33,6				

m	$t°$	Cl ‰	S ‰	σ_t	O'_2	O_2	$\frac{100\,O_2}{O'_2}$	p_H
19	17,7		35,0					
20	8		37,8					
25	4		38,6					
15	23,6		23,8					

Stat. **181**. 13. Aug. 1910. 2 p. m. 38° 49′ N, 25° 09 E; depth 255 m.

0	24,55	21,05	38,03	25,79	4,84	4,57	94,4	8,27
10	2	12	15	99	86	63	95.3	
15	21,6	34	55	27,04	5,04	5,09	101,0	
20	19,75							
25	17,85	26	40	93	35	50	102,9	
50	15,54	39	64	28,67	54	53	99,8	
100	14,83	51	86	29,00	60	17	92,3	8,25
150	59	53	89	08	64	09	90,3	
240	02	51	86	18	68	08	89,5	8,17

Stat. **182**. 13. Aug. 1910 9 p. m. 38° 13′ N, 24° 48′ E; depth 500 m.

0	25,5	20,28	36,64	24,45	4,80	4,60	95,8
10	5	45	94	67	79	62	96,4
25	22,05	89	37,74	26,31	5,03	5,15	102,3
30	18,0	21,12	38,15	27,71	34	59	104,7
35	17,0	19	28	28,04	43	65	104,1
50	16,25	33	53	41	48	70	104,0
75	15,0	41	68	82	60	55	99,1
100	14,72	47	78	97	62	30	94,3
200	32	50,5	85	29,11	66	21	92,1
300	04	51	86	18	69	21	91.6
400	13,72	49	82	22	72	14	89,9
490	39	48	80	27	75	03	87,5

Strong current from NE.

Stat. **183**. 16. Aug. 1910. 4 p. m. 37° 52′ N, 23° 09′ E; depth 233 m.

0	25,8	21,11	38,13	25,47	4,73	4.64	98,1	8,25
10	8	09	10	45	73	59	97.1	8,25
25	5	12	15	58	76	70	98,7	8.25
40	20,0	28	44	27,40	5,16	5,53	107,1	
50	17,11	34	55	28,23	41	65	104,4	8,21
75	14,82	36	58	80	61	49	97,9	
100	13,90	38	62	29,03	70	04	88,4	8.17
125	21	36	58	14	78	4,59	79,4	
150	12,75	34	55	21	83	45	76,3	8,12
225	61	32	51	21	85	54	77,6	8,09

Stat **184**. 16. Aug. 1910. 10 p. m. 38° 10′ N, 22° 33′ E; depth 842 m.

0	23,9	21,12	38,15	26,08	4,88	4,82	98,8
10	95	10	12	03	88	84	99,1
25	22,5	07	06	42	99	5,11	102,4
35	18,1	05	03	27,58	5,34	72	107,1
50	14,7	16	22	28,54	63	78	102,7
100	13,45	26	40	95	76	20	90,2
200	12,81	34,5	56	29,20	83	00	85,8
300	76	35	57	22	83	03	86,3
400	76	35	57	22	83	05	86,6
500	77	35	57	22	83	08	87,2
700	81	36	58	23	83	11	87,6
825	82	36	58	23	84	09	87,2

Stat. **186**. 17. Aug. 1910. 8[30] p. m. 37° 57′ N, 19° 51′ E; depth > 3000 m.

0	24,0	21,15	38.21	26.09			
10	23,95	15	21	10	4,89	4,63	94,6
20	21,7				5,05	5,10	101,0
25	18,3	15	21	27,67	31	62	105,8
50	15,5	17	24	28,37	54	86	105,7
75	14,5	27	42	74	64	44	96,4
100	13,79	28	44	90	71	08	88,9
125	81	35	57	29,00	71	4,74	83,0
150	14,02	42	69	06	69	64	81,5
200	01	45	75	10	67	64	81,8
300	13,93	47	78	15	69	56	80,2
400	84	46	77	15	70	46	78,2

m	$t°$	Cl ‰	S ‰	σ_t	O'_2	O_2	$\frac{100\ O_2}{O'_2}$	p_H
600	13,73	21,44	38,73	29,15	5,73	4,32	75,4	
800	65	42	69	14	72	27	74,7	
1000	61	42	69	15	73	15	72,4	
1250	59	41,5	68	14	74	13	72,0	
1500	57	41	68	13	74	13	72.0	
Stat. **187**. 18. Aug. 1910. 3 p. m. 37° 54′ N, 18° 02′ E; depth > 2500 m.								
0	25,05	21,26	38,40	25,91	4,78	4,60	96,2	
25	24,0	22	33	26,19	87	64	95,3	
35	20,2	14	19	27,16	5,15	5,43	105,5	
50	17,4	15	21	89	39	65	104,4	
75	15,94	16	22	28,26	51	73	104,0	
100	10	17	24	47	59	62	100,6	
150	14,47	26	40	73	65	09	90,1	
190	27	37	60	92	66	4,81	85,0	
250	10	41	68	29,02	68	77	84,0	
300	13,83	41	68	08	71	72	82,6	
400	91	46	77	13	72	47	78,3	
600	70	44	73	16	72	32	75,5	
1000	57	42	69	15	72	23	73,9	
Stat **189**. 19. Aug. 1910. 11 a. m. 37° 44′ N, 15° 58′ E; depth < 2000 m.								
0	25,9	21,20	38,30	25,58	4,72	4,49	95,2	8,29
10	24,8	16	22	87	80	55	94,8	8,29
20	20,4				5,15	5,28	102,5	
25	18,6	20,93	37,81	27,29	30	44	102,6	
50	16,2	21,11	38,13	28,12	49	59	101,9	8,25
75	14,77	16	22	53	62	14	91,4	
100	65	30	48	74	64	05	89,6	8,21
150	18	41	68	29,00	68	4,61	81,2	8,19
175	21	43	71	03	67	69	82,7	
200	23	47	78	08	67	60	81,2	8,19
250	13	47	78	10	68	58	80,7	
300	13,99	46,5	77	12	69	42	77,7	8,17
400	48	41	68	15	75	39	76,4	8,17
600	53	41	68	14	74	36	76,0	8,17
800	53	41	68	14	74	33	75,4	8,14
1000	53	41	68	14	74	29	74,7	
1200	48	41	68	15	75	21	73,2	8,14
1350	44	41	68	16	75	33	75,3	
Stat. **192**. 20. Aug. 1910. 8—9^{30} p. m. 38° 07′ N, 15° 35′ E; depth 652 m.								
0	23,5	21,20	38,30	26,32	4,90	4,87	99,4	
10	21,75	13	17	72	5,04	90	97,3	
25	18,80	12	15	27,51	27	5,15	97,8	
50	16,97	16	22	28,01	41	4,98	92,1	
75	14,41	27	42	76	66	61	81,4	
100	29	30	48	83	67	60	81,2	
150	13,82	40	66	29,07	71	39	77,0	
175	79				71	37	76,5	
200	75	41,5	68	11	72	37	76,4	
300	58	42	69	15	75	33	75,3	
400	56	42	69	16	75	23	73,6	
625	55	42	69	16	74	19	73,0	
Stat. **194**. 21. Aug. 1910. 7—9^{30} a. m. 38° 33′ N, 15° 29′ E; depth 1140 m.								
0	25,4	20,99	37,92	25,44	4,77	4,58	96,0	8,27
10	2	96	86	49	78	59	96,0	
25	21,5	84	65	26,38	5,08	5,11	100,6	
35	18,6	81	59	27,13	31	60	105,4	
50	16,18	84	65	75	52	71	103,4	
75	14,59	97	88	28,30	66	64	99,6	
87	79				64	27	93,4	
100	52	21,12	38,15	52	66	17	91,3	8,25
150	13,71	15	21	74	74	4,91	85,5	
175	63				75	80	83,5	
200	71	23	35	86	74	59	80,0	8,17
300	93	39	64	29,03	70	25	74,6	8,14
400	89	39,5	64	04	69	22	74,1	8,14
600	81	40	66	07	71	20	73,6	8,12
800	68	38	62	07	72	18	73,1	8,12
1000	56	36	58	07	72	25	74,3	8,09

m	$t°$	Cl ‰	S ‰	σ_t	O'_2	O_2	$\frac{100\ O_2}{O'_2}$	p_H
Stat. **195**. 21. Aug. 1910. 3—6 p. m. 39° 02′ N, 14° 55′ E; depth c. 3160 m.								
0	26,0	21,05	38,03	25,34	4,72	4,55	96,4	8,27
10	25,05	03	37,99	62	80	40	91,6	
25	21,95	20,92	79	26,38	5,03	5,18	103,0	8,23
35	17,55				40	79	107,2	
50	15,5	96	86	28,09	57	76	103,4	8,21
75	14,26				69	58	98,1	
100	13,82	21,13	38,17	69	73	4,98	86,9	8,14
150	65	22	33	86	75	65	80,9	
200	93	33	53	95	70	23	74,2	8,14
400	90	41	68	29,06	71	19	73,4	8,12
600	70	39	64	08	72	19	73,3	8,12
800	45				76	12	71,5	8,12
1000	33	31	49	05	79	12	71,2	
1250	20				80	10	70,7	8,09
1500	17	29	46	06	79	05	69,9	8,09
2000	13	27	42	04	79	09	70,6	8,09
Stat. **197**. 24. Aug. 1910. 8^{30}—10 p. m. 40° 34′ N, 13° 36′ E; depth > 1000 m.								
0	23,9	21,01	37,95	25,93	4,88	4,81	98,5	
10	24,0	03	99	93	88	73	97,0	
25	19,9	20,98	90	27,02	5,19	5,48	105,7	
50	15,6	98	90	28,10	56	83	104,9	
100	14,0	21,07	38,06	48	70	43	95,2	
150	13,82	24	37	84	72	4,54	79,4	
200	93	32	51	93	72	35	76,1	
400	88	39	64	29,04	71	21	73,8	
1000	38	34	55	08	75	16	72,4	
Stat. **199**. 25. Aug. 1910. 6^{30}—8 p. m. 39° 32′ N, 10° 49′ E; depth c. 2700 m.								
0	24,9	21,17	38,24	25,84	4,80	4,72	98,3	
10	6	14	19	90	82	71	97,7	
25	21,2	05	03	26,76	5,09	5,36	105,3	
35	17,2				41	80	107,3	
50	15,81	08	08	28,18	53	6,04	109,2	
75	14,41	11	13	53	67	5,80	102,3	
100	13,72	14	19	72	75	27	91,6	
150	54	23	35	89	76	4,72	81,9	
200	63	30	48	97	75	58	79,7	
300	83	37	60	29,02	71	33	75,9	
400	79	39	64	06	71	25	74,4	
600	55	34	55	04	73	22	73,6	
1000	25	31	49	07	79	16	71,9	
Stat. **202**. 26. Aug. 1910. 3^{15}—4^{45} p. m. 38° 59′ N, 9° 25′ E; depth 760 m.								
0	24,5	21,15	38,21	25,94	4,84	4,76	98,3	8,21
10	23,75	13	17	26,14	88	62	94,7	8,21
20	21,3							
25	17,95	20,97	37,88	27,51	5,35	5,79	108,2	8,19
50	14,35	91	77	28,27	69	61	98,6	8,14
75	08	21,06	38,04	54	71	67	99,3	
100	13,80	15	21	72	74	26	91,7	8,12
125	54				76	4,90	85,1	
150	43	20	30	88	77	76	82,5	
200	62	27	42	93	74	48	78,1	8,07
300	73	34	55	29,00	72	24	74,1	8,07
400	63	37	60	07	73	23	73,8	8,07
600	49	33,5	54	05	75	09	71,1	8,07
750	36	32	51	06	76	00	69,5	8,07
Current from SSE.								
Stat. **204**. 27. Aug. 1910. 6^{45}—8^{30} a. m. 38° 52′ N, 7° 43′ E.								
0	23,50	21,14	38,19	26,23	4,91	4,77	97,2	8,14
10	52	11	13	18	91	77	97,2	
15	22,7							
25	18,5	04	01	27,46	5,30	5,60	105,7	
50	14,7	03	37,99	28,36	65	98	105,8	
100	13,26	13	38,17	81	78	4,89	84,6	
125	22				80	52	78,0	
150	22	22	33	95	79	33	74,7	8,09

m	$t°$	Cl ‰	S ‰	σ_t	O'_2	O_2	$\frac{100\ O_2}{O'_2}$	p_H
200	13,43	21,29	38,44	28,98	5,76	4,14	71,9	
300	35	32	51	29,06	76	04	70,1	
400	28	31,5	50	06	76	01	69,6	
600	25	32	51	08	78	07	70,4	
800	00	27	42	06	81	18	71,9	
1000	12,92	25	39	05	82	08	70,1	8,09

Stat. **206**. 28. Aug. 1910. 4^{45}—9^{30} a. m. 39°32 N, 5°15′ E; depth c. 2860 m.

0	24,9	20,70	37,39	25,21	4,81	4,66	96,8	
10	95	71	41	21	82	66	96.7	
25	6	21,01	95	72	82	76	98,7	
35	22,8				96	5,18	104,4	
40	20,45	20.92	79	26,79	5.15	60	108,7	
50	17.6	98	90	27,61	38	6,07	112,8	
75	14,55	21,07	38,06	28,46	66	5,85	103,3	
100	13,43	11	13	74	76	10	88,6	
150	02	18	26	93	78	4,59	79,4	
175	05	21	31	96	82	51	77,5	
200	12,91	20	30	98	77	93	85.4	
250	85	22,5	34	29,03	81	65	80,0	
300	94	24,5	38	04	81	35	74,9	
400	94	25	39	05	82	10	70,5	
600	89	24,5	38	05	83	10	70,3	
800	82	23,5	36	05	83	10	70,3	
1000	83	24	37	05	83	14	71,0	
1250	88	24	37	04	82	16	71,5	
1500	94	24,5	38	04	82	49	77,1	
2000	98	24	37	02	81	66	80,2	
2500	13,02	24	37	01	82	56	78,4	

Stat. **207**. 28. Aug. 1910. 10 p. m. 39°58′ N, 3°41′ E; depth 51 m.

0	24,95	20.91	37,77	25,48	4,81	4,55	94,5	
10	85	92	79	53	81	53	94,1	
25	21.3	94	83	26,59	5,09	5,36	105.4	
35	16,9				44	94	109,1	
50	15,04	21,02	97	28,27	62	65	100,6	

Stat. **209**. 29. Aug. 1910. 9^{30} a. m. 12 md. 40°34′ N, 3°03′ E; depth > 2000 m.

0	24,5	21.09	38,10	25.86	4,83	4,70	97,3	8,25
10	3	06	04	88	85	68	96,4	8,23
25	23,85	06	04	26.01	89	79	98,0	8,21
35	19.3				5,24	5,61	107.1	
50	15.75	08	08	28,19	53	99	108.3	8,21
75	13.66	15	21	75	75	57	96,8	
100	22	20	30	92	79	08	87.7	8,14
150	12,90	22	33	29.01	81	4,96	85,3	
200	74	22	33	05	84	88	83,6	
300	73	22	33	05	84	69	80.3	8,09
400	74	23	35	06	84	48	76.7	
600	76	24	37	06	83	43	76,0	
800	78	24,5	38	07	83	50	77.2	8,09
1000	80	24	37	06	82	48	77.0	
1250	85	25	39	07	82	48	77,0	8.12
1500	87	25	39	06	81	50	77.4	8,12

Stat. **210**. 30. Aug. 1910. 12^{20}—2^{30} a. m. 41°10′ N, 2°23′ E; depth 780 m.

0	24,00	20,98	37,90	25,85	4,88	4,77	97,7	
25	22,45	96	86	26,29	5,00	96	99.1	
50	19,5	92	79	27,05	23	5,24	100.2	
75	15,5	21,03	99	28.18	57	58	100.2	
100	13,70	12	38.15	70	74	44	94,7	
150	23	22	33	95	80	4,60	79.3	
175	24	23	35	95	80	54	78,3	
200	23	25	39	99	79	53	78.2	
300	07	26,5	41	29,04	80	42	76,2	
400	12,89	26,5	41	08	82	49	77,1	
500	84	26	40	08	83	62	79,3	
750	80	25	39	08	82	42	75,9	

Stat. **214**. 31. Aug. 1910. 12 a. m. 39°39′ N, 0°39′ E; depth 165 m.

0	24,55	20.92	37.79	25,62	4,84	4,69	97,0	8,25
10	53				84	70	97,1	8,27
25	21,65	20,86	37,68	26,37	5,06	5,22	103,2	
50	17,33	89	74	27,55	42	55	102,4	8,19
75	14,55				67	68	100,2	
100	13,48	21,11	38,13	28,73	77	22	90,4	8,14
150	20	17	24	88	80	4,77	82,3	8,12

Stat. **215**. 31. Aug. 1910. 7^{10}—9^{15} p. m. 39°14′ N, 0°52′ E; depth 1050 m.

0	25,02	20,79	37,56	25,30	4,80	4,69	97,6	
25	18,75	60	21	26,79	5,31	5,94	111,9	
50	15,45	21,04	38.01	28,20	56	96	107,1	
100	13.06	12	15	84	82	4,95	85,0	
125	00	15	21	89	82	89	84,0	
150	12	17	24	89	81	82	83,0	
200	01	19	28	94	82	83	83,0	
250	12,74	19	28	29,00	83	86	83,3	
300	76	22	33	04	84	66	79,8	
600	73	24	37	07	84	50	77,1	
1000	76	23	35	05	83	30	73,8	

Stat. **217**. 1. Sept. 1910. 11 a. m. 1^{35} p. m. 38°01′ N, 1°48′ E; depth > 2000 m.

0	24,8	20,42	36,89	24,85	4.84	4,67	96,5	8,26
10	4	39	83	93	88	70	96,3	8.26
20	21,6				5,09	5,32	104.5	
25	17,3	38	82	26,85	44	82	107.0	8,24
50	14,38	84	37,65	28.16	69	08	89,3	8,20
75	13,39	21,03	99	65	78	4,91	85,0	
100	26	07	38,06	73	80	72	81,4	8.14
150	12,85	15	21	92	82	78	82,1	
200	90	20	30	98	82	45	76,5	8,14
300	94	24	37	29,03	82	25	73,1	
400	87	24,5	38	05	82	05	69,6	
600	86	24	37	04	82	04	69,4	8,14
950	84	23,5	36	04	83	3,99	68,4	8,12
1500	91	24,5	38	04	82	4,31	74,0	8,12
2000	96	24	37	02	81	53	78,0	

Stat. **218**. 2. Sept. 1910. 3^{45} 5^{45} a. m. 36°34′ N. 2°57′ E: depth c. 2000 m.

0	23,50	20,34	36,74	25,13	4,95	4,83	97,6	
10	45	32	71	11	95	88	98.6	
15	22,1				5,06	5,17	102,2	
20	18,0				39	88	109.1	
25	17,10	22	53	26,68	47	70	104,3	
50	15,17	34	74	27,29	64	25	93,1	
75	14,88	42	89	47	67	00	88,2	
100	30	64	37,29	90	72	4,75	83,0	
125	13,62	21,00	94	28.55	76	80	83,4	
150	07	12	38,15	84	81	64	79.9	
175	12,99				82	68	80,4	
200	95	17	24	93	82	52	77.6	
300	98	24	37	29,02	82	20	72,2	
400	96	26,5	41	06	81	11	70.7	
600	88	25	39	06	81	14	71,3	
950	84	24,5	38	06	83	22	72,4	

Stat. **222**. 4. Sept. 1910. 8^{35}—10 p. m. 35°53′ N, 0°57′ W; depth c. 2000 m.

0	22,88	20,28	36,64	25,23	4,98	4,95	99,3	
10	85	27	62	22	5,01	82	96,3	
20	18,7				34	5.73	107,4	
25	17,1	18	45	26,62	47	86	107,2	
50	15,12	32	71	27,28	66	55	98,1	
75	14,25	53	37,09	76	73	4,59	80,1	
100	13.82	82	61	28,26	75	39	76.4	
125	32	21,08	38,08	73	79	55	78,6	
150	05	14	19	87				
200	12,85	17	24	95	84	47	76.6	
300	85	21	31	29,01	84	35	74.5	
400	13,00	26	40	04	81	00	68,8	
500	12,93	26	40	06	82	3,97	68,2	
600	90	24,5	38	04	82	4,11	70,6	
800	82	25	39	07	82	18	71,8	

Current from W, force irregular.

m	$t°$	Cl ‰	S ‰	σ_t	O'_2	O_2	$\frac{100\,O_2}{O'_2}$	p_H
Stat. **223**. 5. Sept. 1910. 7^{15}—10 a. m. 36° 13′ N, 1° 28′ W; depth ~ 2000 m.								
0	22,9	20.24	36,56	25,17	5,01	4,91	98,1	8,28
10	9	24	56	17	00	90	98,0	8,26
25	20,20	17	44	82	22	5,58	107,0	
50	16,78	17	44	26,69	51	65	102,5	
75	15,64	24	56	27,05	61	25	93,6	8,22
100	01	29	65	26	67	02	88,5	8,22
125	14,60	39	83	50	70	4,88	85,7	
150	09	64	37,29	95	74	46	77,7	
200	13,17	21.13	38,17	28,83	80	24	73,1	8,20
250	12,97				81	04	69,6	
300	95	21	31	98	80	3.95	68,1	8,14
400	98	26	40	29,05	81	82	65,8	8,12
600	93	25	39	05	82	95	67,9	8,09
950	92	25	39	05	83	4,12	70,7	8,09
1500	93	25	39	05	82	45	76,4	8,09
2000	97	25	39	04	81	48	77,1	8,09
Current strong and irregular.								
Stat. **224**. 5 Sept. 1910. 5—7 p. m. 36° 33′ N. 2° 00′ W; depth 950 m.								
0	23,7	20,28	36,64	25,00	4,94	4,81	97,4	
10	45	27	62	05	95	84	97,7	
25	21,75	19	47	43	5.09	5,28	103,7	
35	18,1				38	85	108,7	
50	16,65	20	49	26,76	51	73	103.9	
75	15.75	23	55	27,01	58	30	95,0	
100	15	27	62	20	66	13	90,6	
150	14.62	33	73	41	71	04	88.3	
200	13,87	80	37,57	28,22	74	4,97	86,5	
250	05	21,15	38,21	88	80	82	83.1	
300	12,85	16	22	94	83	65	79,7	
400	90	20	30	98	82	20	72.2	
500	98	26	40	29,05	82	3,91	67,2	
600	92	26	40	06	82	96	68,0	
950	88	24,5	38	05	82	4,16	71,5	
Stat. **228**. 7. Sept 1910. 4—6 a. m. 36° 02′ N, 5° 06′ W; depth 720 m.								
0	18,42	20.18	36,45	26,30	5,36	5,24	97,7	
25	17,10	21	51	66	48	07	92,5	
50	15.02	36	78	27,36	66	4,68	82,7	
75	14,31	51	37,05	72	72	50	78,7	
100	13.70	73	45	28.16	78	30	74,4	
125	42	94	83	51	79	12	71.2	
150	16	21,07	38.06	75	81	00	68,9	
200	12,95	21	31	98	83	3,70	63,5	
250	89	25	39	29,06	81	73	64,2	
300	87	25	39	06	82	79	65,1	
400	84	26	40	08	81	89	66,9	
500	80	26	40	09	81	4,08	70,2	
700	12,77	25	39	08	83	16	71,3	
Strong current from W, 3—4 miles/hour.								
Stat. **229**. 8. Sept. 1910. 8^{20}—10 a. m. 35° 51′ N, 5° 58′ W; depth 485 m.								
0	21.45	20,16	36,42	25,47	5,12	5,12	100,0	
10	30	13	36	48	13	08	99.0	
25	19,38	09	29	93	28	43	102,7	
50	15.18	01	15	26,83	67	18	91,4	
75	14.41	19,97	08	95	75	4,95	86,0	
100	13.82	90	35,95	97	81	94	85.0	
125	56	89	93	27,02	84	92	84.2	
150	23	85	86	03	89	80	81,5	
175	12,77	83	82	09	92	80	81,1	
200	71	87	90	16	94	72	79,4	
225	84	97	36,08	27	93	70	79,3	
250	13,20	20.51	37,05	96	85	47	76,4	
300	19	61	23	28,10	84	41	75.5	
400	11	92	79	55	83	11	70,5	
475	03	21,12	38.15	85	82	10	70,5	

m	$t°$	Cl ‰	S ‰	σ_t	O'_2	O_2	$\frac{100\,O_2}{O'_2}$	p_H
Stat. **230**. 8. Sept. 1910. 11 a. m. 12 md. 35° 57′ N, 6° 00′ W; depth 290 m.								
0	21,00	20,09	36.29	25,50	5.16	5,01	97.1	8.24
25	20.19	07	26	68	22	4.94	94,6	
50	15.72	01	15	26,71	62	5,33	94,8	8.20
100	14,44	19,96	06	93	74	4,76	83,0	
150	30	91	35.97	89	77	64	80.4	8,15
175	13,43	20,06	36,24	27.28	86	47	76,3	
200	35	33	73	68	84	40	75,4	
225	27	67	37.34	28,16	81	22	72,6	
250	11	93	81	56	84	04	69.2	8,13
275	12	96	86	61	83	13	70,8	
Stat. **231**. 8. Sept. 1910. 10—11^{30} p. m. 35° 56 N, 7° 16 W; depth 950 m.								
0	21,30	20,16	36,42	25,51	5,13	4,88	95,2	
10	30	16	42	51	13	91	95,8	
25	19,04	09	29	26,02	31	5,27	99,2	
50	16,24	07	26	67	56	53	99.5	
100	14,86	19,98	09	87	72	4,87	85,1	
150	20	92	35,99	92	78	68	81,0	
200	13,45	87	90	27,01	86	64	79.2	
300	12.33	77	71	10	99	60	76,8	
400	11,56	71	61	16	6,09	45	73,1	
600	10.89	75	68	34	18	09	66.2	
800	79	86	88	51	18	3.87	62,6	
950	53	90	95	61	21	94	63.4	
Stat. **232**. 9. Sept. 1910. 7—8^{45} p. m. 36° 28′ N, 9° 06′ W; depth c. 3500 m.								
0	22,5	20,25	36,58	25,30	5,03	5,09	101.2	
25	5	24	56	29	03	4,82	95,8	
35	18,6				35	5,69	106,3	
50	16,94	05	22	26.48	51	75	104.3	
100	14,55	19.96	06	90	74	13	89.3	
200	13.23	85	35,86	27,03	90	4,81	81.5	
400	11,46	71	61	18	6,09	57	75,0	
600	10,83	75	68	35	17	01	65,0	
800	11,08	92	99	54	13	3,91	63.8	
900	10,34	90	95	65	23	83	61.5	
950	35	90	95	65	23	86	62,0	
Stat. **234**. 10. Sept. 1910. 5^{30}—7 p. m. 38° 10′ N, 9° 20′ W; depth 910 m.								
0	19.30	19,88	35,91	25,67	5,30	5.37	101.3	
25	17,00	89	93	26.25	50	67	103,0	
50	14,18	91	97	91	78	4,97	86,0	
100	13.73	90	95	99	83	71	80,8	
200	12,59	82	81	27,12	96	60	77,2	
400	11,36	75	68	25	6,10	51	73,9	
500	20	80	77	36	13	29	70,0	
600	60	90	95	42	06	22	69,6	
700	12,27	20,07	36,26	53	5.98	22	70,7	
800	16	07	26	55	99	17	69,6	
875	11,97	10	31	63	6,00	15	69,2	
Stat. **242**. 16. Sept. 1910. 4—5^{45} p. m. 46° 19′ N, 6° 48′ W; depth ~ 4000 m.								
0	17,34	19,69	35,57	25,89	5,49	5.40	98,3	
10	20	66	52	87	49	34	97,2	
25	15,25	66	52	26,33	68	52	97,2	
35	13,98	66	52	60	82	41	93,0	
50	12.24	66	52	96	6,01	47	91,0	
75	11,51	66,5	52	27,11	09	41	88.8	
100	18	67	53	18	13	52	96,0	
200	10,86	66,5	52	22	18	51	89,2	
400	67	66,5	52	26	21	32	85,7	
600	33	68	55	34	24	4.80	76,9	
800	9,96	75	68	50	28	37	69.6	
875	93	79	75	57	27	30	68,6	
950	94	82	81	61	27	18	66,7	
Stat. **244**. 17. Sept. 1910. 9^{15} a. m. 47° 08′ N. 6° 08′ W.								
0	16,84	19,65	35.50	25.95	5,54	5,41	97,6	
800	10,02	73	64	27,47	6,27	4,41	70,3	
940	9,81	80	77	61	28	34	69,1	

2. Observations made during the "Thor" Expeditions 1905 and 1906 in the Atlantic S. of Ireland.

1905

Stat. **79**, 1905, VI, 13
53°06′ N, 10°47′ W
130 m

m	t°	S ‰	σ_t
0	13,36	35,34	26,60
25	12,45	32	76
30	11,65	30	91
37	10,68	37	27,15
50	00	43	30
87	9,37	43	41
125	33	43	41

Stat. **80**, 1905, VI, 13
52°06′ N, 11°10′ W
144 m

m	t°	S ‰	σ_t
0	14,11	35,52	26,58
25	11,94	50	27,01
37	39		
50	10,48	46	24
100	13	47	31
142	02	47	33

Stat. **82**, 1905, VI, 15
51°00′ N, 11°43′ W
1350 m

m	t°	S ‰	σ_t
0	13,79	35,46	26,60
25	20	47	73
37	12,35		
50	11,29	43	27,07
100	10,52	44	22
400	17	46	31
800	9,40	49	45
1000	8,58	53	63
1100	21	52	67
1300	6,85	34	73

Stat. **84**, 1905, VI, 18
51°24′ N, 8°18′ W
95 m

m	t°	S ‰	σ_t
0	14,25	35,23	26,33
25	03	21	36
37	9,64		
50	64	26	27,24
90	64	23	25

Stat. **85**, 1905, VI, 19
50°19′ N, 8°30′ W
120 m

m	t°	S ‰	σ_t
0	14,22	35,37	
25	18	37	
37	11,99		
50	10,85	34	
115	9,88	31	

Stat. **86**, 1905, VI, 19
49°14′ N, 8°45′ W
95 m

m	t°	S ‰	σ_t
0	14,05	35,39	26,50
50	10,23	32	27,18
90	22	32	18

Stat. **90**, 1905, VI, 21
47°47′ N, 8°00′ W
1012 m

m	t°	S ‰	σ_t
0	14,40	35,53	26,54
25	13,00	53	83
50	12,82	53	87
100	11,70	56	27,10
200	06	59	24
400	10,77	58	29
600	10,47	35,60	27,36
800	00	61	45
1000	9,47	64	56

Stat. **93**, 1905, VI, 25
49°53′ N, 11°51′ W
1180 m

m	t°	S ‰	σ_t
0	15,10	35,52	26,37
50	13,82	50	63
75	11,52		
100	10,92	44	27,14
250	33	44	25
400	00	44	31
800	9,35	48	45
1000	8,81	55	60
1150	10	53	70

Stat. **94**, 1905, VI, 27
50°02′ N, 6°20′ W
86 m

m	t°	S ‰	σ_t
0	14,74	35,26	26,25
45	12,21	28	78
85	11,82	26	84

Stat. **96**, 1905, VI, 27
50°15′ N, 4°19′ W
50 m

m	t°	S ‰	σ_t
0	15,10	35,21	26,14
25	12,01	35	88
48	11,63	39	98

1906

Stat. **27**, 1906, V, 1
50°00′ N, 2°25′ W
69 m

m	t°	S ‰	σ_t
0	8,45	35,14	27,34
10	55	14	32
30	60	16	32
68	75	16	30

Stat. **28**, 1906, V, 1
50°08′ N, 4°09′ W
58 m

m	t°	S ‰	σ_t
0	8,70	35,14	27,30
20	51	14	33
56	48	14	33

Stat. **30**, 1906, V, 7
50°11′ N, 4°18′ W
51 m

m	t°	S ‰	σ_t
0	9,13	35,14	27,23
10	06	16	25
30	01	17	28
50	8,99	19	29

Stat. **31**, 1906, V, 7
49°45′ N, 4°42′ W
98 m

m	t°	S ‰	σ_t
0	9,90	35,28	27,21
10	69		
25	66	30	27
50	65	30	27
95	66	30	27

Stat. **32**, 1906, V, 7
48°40′ N, 5°04′ W
113 m

m	t°	S ‰	σ_t
0	9,91	35,39	27,28
25	90	41	30
50	91	41	30
110	92	41	30

Stat. **33**, 1906, V, 8
48°00′ N, 4°52′ W
35 m

m	t°	S ‰	σ_t
0	10,30	35,07	26,97
10	10	08	27,01
25	10	08	01
34	10	08	01

Stat. **35**, 1906, V, 8
47°05′ N, 4°26′ W
146 m

m	t°	S ‰	σ_t
0	12,20	35,25	26,75
10	11,17	36	27,05
25	10,73	37	14
50	58	35	15
140	30	52	32

Stat. **37**, 1906, V, 10
44°01′ N, 2°49′ W
1395 m

m	t°	S ‰	σ_t
0	13,13	35,59	26,83
10	10	59	84
25	11,74	53	27,07
50	46	59	16
100	37	64	22
200	30	65	24
400	00	64	29
600	10,50	64	38
800	06	75	55
1000	9,62	79	65
1200	8,71	69	72
1390	7,22	52	81

Stat. **41**, 1906, V, 14
43°23′ N, 2°01′ W
102 m

m	t°	S ‰	σ_t
0	15,00	34,72	25,77
10	13,88	35,21	26,39
25	11,85	50	27,03
50	57	52	09
100	45	61	18

Stat. **43**, 1906, V, 15
43°37′ N, 2°08′ W
1140 m

m	t°	S ‰	σ_t
0	14,06	34,99	26,19
25	11,76	35,34	92
100	38	58	27,17
400	03	64	28
800	10,10	74	54
1130	9,23	77	70

Stat. **44**, 1906, V, 16
43°58′ N, 1°27′ W
40 m

m	t°	S ‰	σ_t
0	15,70	30,72	22,54
10	12,85	34,72	26,22
20	11,89		
39	83	35,28	26,85

Stat. **49**, 1906, V, 18
46°13′ N, 4°24′ W
1700 m

m	t°	S ‰	σ_t
0	12,03	35,57	27,04
25	11,93	59	07
50	43	62	20
100	12	64	27
400	10,85	62	31
1000	9,64	75	61
1200	8,70	23,70	27,74
1400	7,95	61	79
1700	6,12	37	85

Stat. **51**, 1906, V, 20
48°07′ N, 9°03′ W
1920 m

m	t°	S ‰	σ_t
0	11,36	35,60	27,19
25	36	59	18
50	35	60	19
100	21	58	21
400	10,78	58	28
800	9,89	59	45
1000	48	64	56
1200	8,50	62	71
1400	7,05	44	77
1600	9,99	31	82
1800	4,84	19	87

Stat. **60**, 1906, V, 31
51°27′ N, 11°10′ W
198 m

m	t°	S ‰	σ_t
0	10,90	35,30	27,05
25	69	30	08
50	34	35	19
100	9,91	43	32
195	73	45	37

Stat. **62**, 1906, VI, 5
50°16′ N, 12°55′ W
2775 m

m	t°	S ‰	σ_t
0	12,00	35,50	27,00
25	11,69	46	03
50	03	48	15
100	10,61	46	22
400	03	44	30
600	9,63	39	33
800	8,71	39	49
1000	05	44	63
1200	6,68	31	72
1500	4,73	08	79
2000	3,80 [1]	34,97	81

[1] During the hauling-up the waterbottle was stopped (about 15 min.) at a depth of about 1600 meters, the temperature 3°80 is probably too high.

Stat. **66**, 1906, VI, 6
48°41′ N, 15°17′ W
> 4000 m

m	t°	S ‰	σ_t
0	13,70	35,61	26,74
100	11,52	57	27,14
400	10,69	52	24
1000	8,30	34	51

Stat. **68**, 1906, VI, 7
48°04′ N, 12°40′ W
> 4000 m

m	t°	S ‰	σ_t
0	13,30	35,52	26,75
25	12,33	52	94
50	11,62	52	27,08
100	16	53	18
400	10,45	49	27
800	9,53	52	45
1000	00	62	63
1200	7,62	47	71
1500	5,58	22	80
2000	3,60	34,97	83
3500	2,67 [1]	94	89

[1] By waterbottle thermometer; by reversing therm. 2°,69.

Stat. **74**, 1906, VI, 10
49°25′ N, 12°19′ W
1298 m.

m	t°	S ‰	σ_t
0	14,78	35,59	26,49
10	00	55	63
25	12,60	52	89
50	11,40	48	27,09
100	10,85	50 [1]	21
400	32	48	28
600	9,94	48	35
800	31	53	51
1000	8,67	55	62
1275	7,32	47	76

[1] The bottle with the water sample badly corked.

Stat. **79**, 1906, VI, 16
51°37′ N, 11°12′ W
210 m

m	t°	S ‰	σ_t
0	13,47	35,38	26,90
25	11,20	41	27,07
50	10,70	43	17
75	9,83	46	36
100	69	46	38
200	41	48	44

Stat. **81**, 1906, VI, 17
51°29′ N, 11°45′ W
870 m

m	t°	S ‰	σ_t
0	13,27	35,51	26,75
25	11,58	49	27,17
37	10,56		
50	40	35,48	27,27
100	26	48	29
200	9,79	44	34
400	58	46	40
600	04	45	48
800	8,45	52	63

Stat. **83**, 1906, VI, 20
51°58′ N, 10°25′ W
86 m

m	t°	S ‰	σ_t
0	13,35	35,17	24,48
25	12,31	21	71
50	10,85	23	27,00
84	12	26	16

Stat. **84**, 1906, VI, 21
52°54′ N, 9°36′ W
71 m

m	t°	S ‰	σ_t
0	13,64	34,47	25,87
25	10,76	70	26,68
50	9,24	35,12	27,19
70	8,78	12	26

Stat. **164**, 1906, VIII, 23
50°14′ N, 4°24′ W
60 m

m	t°	S ‰	σ_t
0	15,70	35,17	25,97
10	14,32	25	26,32
25	13,05	26	66
58	12,75	26	67

Stat. **165**, 1906, VIII, 24
49°49′ N, 6°20′ W
72 m

m	t°	S ‰	σ_t
0	13,87	35,21	26,49
35	49	23	49
70	40	23	51

	$t°$	S ‰	σ_t
. **166**, 1906, VIII, 25			
50°40 N' 9°32' W			
125 m			
	15,74	35,20	25,98
	14	21	26,13
	14.46		
	9,80		
	70	35,43	27,35
	73	43	35
. **167**, 1906, VIII, 26			
51°28' N, 11°50' W			
1150 m			
	15.80	35,37	26.10
	55	36	15
	13 64		
	11.74	35,46	27,02
	10,71	43	17
	31	43	24
	11	43	28

m	$t°$	S ‰	σ_t
600	9,76	35,43	27,34
800	11	48	49
1000	8,30	50	64
1150	ca. 8,10	48	65
Stat. **170**, 1906, VIII, 29			
51°57' N, 10°27' W			
77 m			
0	15,41	35,25	26,09
10	34		
25	13,29	35,10	26.43
50	11,47	16	82
75	10,67	25	27,04
Stat. **176**, 1906, VIII, 31			
49°31' N, 11°51' W			
1125 m			
0	17,22	35,46	25,84
25	16,62	43	95
37	24		
50	12,48	35,48	26.88

m	$t°$	S ‰	σ_t
100	11,31	35,48	27,10
400	10,27	43	25
800	9,12	43	45
1000	8,41	46	59
1100	10	50	67
Stat. **178**, 1906, IX, 2			
48°04' N, 12°40' W			
4088 m			
0	18,50	35,55	25,59
25	17,71	53	78
50	14,85	55	26,45
75	11,89		
100	56	35,58	27,15
400	10,56	35,50	27,26
800	9,56	46	41
1000	8.75	52	58
1200	7.30 [1]	39	70
1500	5.62 [2]	23	80

[1] Water bottle thermometer, Reserving thermometer gave: 7°28.
[2] Reversing thermometer

m	$t°$	S ‰	σ_t
Stat. **179**, 1906, IX, 3			
47°20' N, 12°23' W			
> 4000 m			
0	19,38	35,61	25,41
400	10,58	48	27,23
1000	8,73	61	66
2000	3,63	34,97	83
Stat. **180**, 1906, IX, 3			
48°19' N, 13°53' W			
ca. 4000 m			
0	17,52	35,52	25,81
50	11,99		
100	54	35,58	27,15
400	10,34	44	25
600	9,77	41	33
800	17	43	44
1000	8,36	50	63
1200	6,75	34	75

m	$t°$	S ‰	σ_t
Stat. **190**, 1906, IX, 11			
46°30' N, 7°00' W			
ca. 4400 m			
0	18,82	35,64	25,57
25	17,82	59	79
37	16,37	59	26,14
50	15,16	59	42
75	13,69	61	74
100	11,74	61	27,14
200	05	59	24
400	10,83	58	27
600	58	58	32
800	35	70	45
1000	9,69	77	62
1200	8.62	64	70
1500	6,47	39	81
2000	4,60	08	80
3500	2,61 [1]	34,97	93

[1] Reversing thermometer.

3. Temperature-Observations made in the Straits of Messina 1911 by Capt. G. Hansen of the "Thor".

Depth m	22—2—11 38° 12′ N 15° 36′ E	22—2—11 38° 09,5′ N 15° 36′ E	24—2—11 38° 10′,5 N 15° 36′ E	25—2—11 38° 11′ N 15° 36,5′ E	1—3—11 38° 13′ N 15° 36,5′ E	8—3—11 38° 12′ N 15° 37′ E	12—3—11 38° 12′ N 15° 37′ E	14—3—11 38° 12′ N 15° 37′ E
0	14°2	14°0	13°80	13°80	13°80	13°80	13°70	13°60
5	13°96	13°96	" "	" 84	" 83	" "	" "	" 72
10	" 92	" 92	" "	" 82	" "	" "	" "	" "
15	" 85	" 85	" "	" "	" 82	" 81	" "	" "
20	" 82	" 82	" 77	" 81	" "	" "	" 75	" "
30	" 80	" 80	" "	" 80	" "	" 80	" 72	" "
40	" 81	" 81	" 75	" 79	" "	" "	" 70	" 70
50	" "	" "	" "	" 78	" 80	" "	" "	" "
60	" 80	" "	.....	" 76	" "	" 75	.....	.....
70	" "	" "	.....	" 75	" "	" "	.....	.....
75	.....	.....	.....	.....	.....	.....	13°68	.....
80	" 81	" "	.....	13°74	13°78	13°75	.....	.....
90	" 80	" "	.....	" 72	" "	" 72	.....	.....
100	" "	" "	13°70	" 71	" "	" "	13°68	13°68
110	.....	.....	.....	" 69	" "	.....	.....	.....
120	.....	.....	.....	" 68	" 76	13°70	.....	.....
130	.....	.....	.....	" 67	" "	" "	.....	.....
140	.....	.....	.....	" 66	" 75	.....	.....	.....
150	13°75	13°77	13°70	" "	" 74	13°70	13°68	13°68
160	.....	.....	.....	" 65	" "	.....	.....	.....
170	.....	.....	.....	.....	.....	.....	.....	.....
180	.....	.....	.....	13°65	13°72	13°70	13°68	.....
200	13°75	13°77	13°70	" "	" "	" 68	" "	13°68
250	.....	.....	.....	.....	.....	.....	" "	" "
300	.....	.....	13°70	.....	.....	.....	" "	" 65

4. Surface Observations.

a) by the Research-Steamer "Thor".

Date	Hour	Lat. N.	Long.	$t°$	$S‰$
10/5 10	9^{35} p. m.	59°11′	4°10′ W	8°3	35,19
11/5 "	6^{30} a. m.	" 33′	5°18′	8°4	" 34
" "	2^{40} p. m.	" 58′	6°12′	8°1	" 26
" "	11^{45} p. m.	60°24′	" 43′	7°15	" 23
12/5 "	6^{35} a. m.	" 48′	" 40′	6°5	" 16
" "	11^{45} a. m.	61°13′	" 39′	6°4	" 19
14/5 "	6^{25} a. m.	" 21′	" 48′	6°6	" 16
" "	11^{10} a. m.	" 16′	7°23′	8°9	" 30
15/5 "	5^{50} a. m.	" 11′	8°04′	8°3	" 25
" "	2^{55} p. m.	" 02′	" 34′	8°4	" 21
" "	7^{40} p. m.	60°43′	" 55′	7°89	" 21
16/5 "	5^{45} a. m.	" 37′	" 50′	7°9	" 24
" "	4^{45} p. m.	" 54′	7°58′	8°28	" 28
" "	8^{00} p. m.	61°03′	" 33′	8°1	" 24
" "	11^{10} p. m.	" 13′	" 14′	6°8	" 17
17/5 "	1^{00} a. m.	" 28′	" 10′	6°6	" 26
" "	3^{00} a. m.	" 43′	" 07′	6°54	" 16
" "	7^{10} a. m.	62°08′	" 09′	6°81	
24/5 "	11^{10} a. m.	61°27′	4°33′	8°35	35,22
26/5 "	8^{00} a. m.	" 35′	5°05′	6°6	34,68
" "	2^{45} p. m.	" 54′	6°12′	6°54	35,08
4/6 "	12^{00} m.	56°26′	7°20′	10°6	34,79
" "	7^{00} p. m.	55°51′	6°45′	9°05	" 13
" "	11^{45} p. m.	" 23′	" 12′	8°9	" 14
5/6 "	4^{00} a. m.	" 08′	5°48′	8°7	" 04
" "	7^{50} a. m.	54°40′	" 23′	8°4	33,95
" "	12^{00} m.	" 01′	" 25′	10°34	" 87
" "	3^{50} p. m.	53°30′	" 27′	10°2	" 91
" "	7^{30} p. m.	" 00′	" 30′	9°58	" 86
6/6 "	0^{30} a. m.	52°21′	" 35′	9°5	34,38
" "	4^{00} a. m.	" "	" 35′	10°2	35,05
" "	8^{00} a. m.	51°37′	" 18′	11°05	
9/6 "	10^{20} p. m.	50°22′	" 32′	11°83	35,12
10/6 "	4^{30} a. m.	49°57′	" 23′	10°84	" 14
12/6 "	4^{25} p. m.	" 31′	" 23′	13°54	" 14
" "	8^{00} p. m.	" 57′	" 42′	13°2	" 08
" "	11^{45} p. m.	48°34′	6°01′	13°82	" 16
13/6 "	3^{30} a. m.	" 07′	" 20′	14°35	" 35
" "	7^{30} a. m.	47°39′	" 39′	13°9	
" "	9^{00} a. m.	" 30′	" 43′	13°9	" 37
" "	11^{30} a. m.	" 12′	" 57′	14°65	" 30
" "	3^{00} p. m.	46°45′	7°14′	15°1	" 25
14/6 "	4^{00} a. m.	45°49′	" 50′	15°4	" 52
" "	7^{30} a. m.	" 22′	8°08′	15°7	" 50
" "	11^{15} a. m.	44°55′	" 24′	15°71	" 53
" "	2^{55} p. m.	" 28′	" 40′	16°15	" 59
" "	6^{45} p. m.	" 02′	" 56′	15°65	" 59
" "	10^{25} p. m.	43°35′	9°14	15°45	" 50
15/6 "	2^{25} a. m.	" 15′	" 33′	15°25	" 62
" "	6^{30} a. m.	42°44′	" 37′	15°71	" 66
" "	10^{30} a. m.	" 16′	" 35′	16°71	" 48
" "	2^{15} p. m.	41°46′	" 34′	18°28	" 44
16/6 "	0^{45} a. m.	" 16′	" 32′	18°0	" 59
" "	4^{40} a. m.	40°47′	" 29′	15°85	" 39
" "	8^{35} a. m.	" 17′	" 27′	17°03	" 39
" "	0^{30} p. m.	39°46′	" 26′	17°68	" 46
" "	9^{45} p. m.	38°51′	" 31′	16°58	34,00
17/6 "	2^{00} a. m.	" 22′	" 28′	16°75	35,59
" "	6^{20} a. m.	37°51′	" 21′	17°35	" 71
" "	11^{00} a. m.	" 22′	" 15′	17°98	" 90
" "	9^{00} p. m.	36°46′	8°48′	18°62	36,38
18/6 "	1^{00} a. m.	" 28′	" 22′	18°98	" 38
" "	8^{45} a. m.	" 10′	7°53′	19°45	" 42
" "	3^{00} p. m.	35°53′	" 26′	19°08	" 47
19/6 "	4^{45} a. m.	36°16′	6°50′	18°01	" 20
22 "	10^{00} p. m.	" 17′	" 17′	19°14	" 04
23/6 "	1^{30} a. m.	" 06′	" 02′	18°48	" 08
24/6 "	4^{25} a. m.	" 10′	4°42′	19°88	" 35
" "	8^{15} a. m.	" 19′	" 06′	18°49	37,52
" "	0^{15} p. m.	" 26′	3°33′	20°6	36,27
24/6 10	4^{00} p. m.	36°34′	2°55′ W	21°29	36,45
" "	8^{30} p. m.	" 43′	" 08′	20°4	" 62
" "	11^{00} p. m.	" 33′	" 00′	20°92	" 56
25/6 "	5^{05} a. m.	" 23′	1°44′	20°88	" 55
" "	10^{30} a. m.	" 13′	" 14′	21°26	" 92
28/6 "	8^{30} p. m.	" 03′	0°27′	21°0	" 53
" "	6^{20} a. m.	" 19′	0°10′ E	20°61	" 55
" "	10^{30} a. m.	" 27′	" 54′	20°79	" 58
" "	2^{05} p. m.	" 36′	1°24′	21°15	" 56
" "	6^{00} p. m.	" 40′	2°00′	22°49	37,16
" "	10^{30} p. m.	" 56′	" 15′	21°96	" 19
28/6 "	2^{00} a. m.	" 53′	3°00′	21°0	" 62
" "	10^{00} a. m.	37°18′	" 28′	20°31	36,67
" "	1^{20} p. m.	" 45′	" 48′	22°29	37,21
" "	8^{00} p. m.	38°17′	4°11′	21°92	" 30
29/6 "	7^{00} a. m.	" 41′	" 34′	21°96	" 32
" "	11^{00} a. m.	39°03′	" 56′	22°52	" 47
" "	10^{00} p. m.	" 27′	5°26′	21°90	" 59
30/6 "	7^{15} a. m.	" 51′	" 49′	21°41	" 19
" "	11^{30} a. m.	40°15′	6°12′	20°98	" 61
" "	8^{30} p. m.	41°00′	" 43′	20°73	" 66
1/7 "	5^{00} a. m.	" 27′	7°00′	19°31	38,28
" "	0^{20} p. m.	42°02′	" 20′	19°20	" 21
" "	6^{00} p. m.	" 31′	" 41′	18°36	" 28
2/7 "	3^{15} a. m.	43°08′	8°05′	18°24	" 28
" "	8^{30} a. m.	" 40′	" 27′	18°83	" 31
9/7 "	2^{00} p. m.	" 50′	" 34′	19°46	" 30
" "	11^{00} p. m.	44°14′	" 55′	20°26	" 35
10/7 "	4^{00} a. m.	" 25′	9°29′	18°40	" 17
11/7 "	3^{00} a. m.	42°14′	10°04′	20°41	37,79
" "	7^{00} a. m.	41°47′	" 22′	19°88	38,37
" "	11^{00} a. m.	" 21′	" 41′	19°96	" 28
" "	2^{30} p. m.	" 01′	" 53′	20°27	" 21
" "	10^{20} p. m.	40°31′	11°13′	21°8	" 22
12/7 "	6^{00} a. m.	" 05′	" 31′	21°76	37,95
13/7 "	1^{00} a. m.	39°35′	" 20′	21°5	" 90
" "	5^{00} a. m.	" 07′	" 10′	20°9	" 72
" "	2^{00} p. m.	38°26′	" 00′	21°48	" 97
" "	8^{00} p. m.	" 47′	10°21′	21°3	" 99
14/7 "	6^{00} a. m.	" 57′	9°47′	20°5	38,01
" "	6^{00} p. m.	" 18′	" 59′	21°82	" 01
19/7 "	3^{50} a. m.	37°01′	10°31′	22°90	37,07
" "	1^{00} p. m.	" 17′	" 50′	22°76	" 27
" "	4^{45} a. m.	" 37′	11°25′	23°50	" 57
20/7 "	2^{00} p. m.	" 29′	12°34′	22°70	37,61
" "	6^{10} p. m.	" 06′	13°02′	23°28	" 57
" "	11^{00} p. m.	36°42′	" 54′	23°76	" 56
21/7 "	3^{50} a. m.	" 22′	14°00′	23°58	" 39
" "	8^{00} a. m.	" 00′	" 29′	23°6	" 65
22/7 "	5^{00} a. m.	35°44′	15°07′	24°05	" 54
" "	12^{00} a. m.	" 30′	" 49′	24°95	" 63
" "	5^{30} p. m.	" 18′	16°25′	25°26	38,01
23/7 "	8^{00} a. m.	" 03′	17°08′	24°8	37,84
" "	7^{00} p. m.	34°31′	18°40′	26°05	38,49
24/7 "	0^{30} p. m.	" 48′	17°41′	26°72	37,72
" "	7^{10} p. m.	33°42′	19°01′	25°6	38,46
" "	11^{20} p. m.	" 13′	" 02′	25°5	" 55
25/7 "	2^{30} p. m.	32°11′	" 02′	25°2	" 40
" "	8^{00} p. m.	31°35′	" 02′	25°20	" 21
26/7 "	7^{30} a. m.	" 05′	" 02′	24°5	" 33
" "	8^{30} p. m.	30°52′	" 15′	24°5	" 40
27/7 "	1^{00} a. m.	31°19′	" 27′	24°16	" 42
" "	5^{00} a. m.	" 42′	" 41′	24°2	" 35
" "	9^{20} a. m.	32°10′	20°00′	24°32	" 28
" "	1^{00} p. m.	" 31′	" 18′	23°9	" 42
" "	5^{10} p. m.	" 48′	" 52′	25°3	" 58
28/7 "	11^{00} a. m.	" 39′	22°15′	24°6	" 57
" "	5^{15} p. m.	" 37′	23°15′	24 45	" 60
" "	10^{00} p. m.	" 27′	" 49′	24°1	" 75
29/7 "	10^{50} a. m.	" 14′	25°21′	24°8	" 80
" "	3^{00} p. m.	" 16′	26°03′	25°4	" 93
30/7 "	9^{30} a. m.	" 50′	27°08′	25°13	39,11
30/7 10	3^{45} p. m.	33°16′	27°18′ E	25°4	39,09
" "	8^{30} p. m.	" 49′	" 30′	24°1	" 16
31/7 "	7^{30} a. m.	34°23′	" 57′	24°1	" 18
" "	2^{15} p. m.	" 52′	28°15′	24°7	" 11
" "	8^{00} p. m.	35°31′	27°55′	24°72	" 23
" "	11^{05} p. m.	" 52′	" 42′	23°8	" 14
1/8 "	6^{30} a. m.	" 59′	28°14′	26°28	" 22
2/8 "	3^{20} a. m.	36°12′	27°16′	23°76	" 14
" "	8^{00} a. m.	" 34′	" 18′	26°5	" 07
"	4^{00} p. m.	37°24′	26°49′	26°0	" 13
" "	10^{00} p. m.	" 52′	" 22′	22°60	" 15
3/8 "	6^{10} a. m.	38°22′	" 14′	22°88	38,89
" "	10^{00} a. m.	" 40′	" 34′	24°4	39,04
4/8 "	9^{00} p. m.	" 48′	" 44′	24°5	" 00
5/8 "	8^{10} a. m.	39°48′	25°59′	24°0	35,53
" "	7^{30} p. m.	40°16′	26°34′	25°02	22,47
6/8 "	0^{30} a. m.	" 36′	27°14′	25°0	21,76
" "	4^{40} a. m.	" 45′	" 51′	24°64	" 38
" "	9^{00} a. m.	" 50′	28°42′	23°5	" 49
11/8 "	8^{00} a. m.	" 48′	27°59′	24°9	" 71
12/8 "	4^{00} a. m.	" 45′	" 43′	24°2	" 76
13/8 "	2^{50} a. m.	" 02′	25°55′	23°9	28,37
" "	7^{10} a. m.	39°34′	" 40′	23°92	34,54
" "	11^{00} a. m.	" 04′	" 21′	24°3	38,64
14/8 "	7^{00} a. m.	37°40′	23°57′	25°4	37,52
16/8 "	4^{00} p. m.	" 52′	" 09′	25°8	38,13
" "	10^{00} p. m.	38°10′	22°33′	23°9	" 15
17/8 "	8^{00} a. m.	" 20′	21°47′	22°6	" 15
" "	11^{30} a. m.	" 12′	" 17′	23°95	" 28
" "	2^{00} p. m.	" 02′	20°51′	24°98	" 22
18/8 "	6^{00} a. m.	37°56′	19°11′	24°7	" 46
" "	3^{00} p. m.	" 54′	18°02′	25°1	" 40
" "	11^{50} p. m.	" 52′	17°23′	25°32	" 49
19/8 "	4^{00} a. m.	" 51′	16°44′	25°27	" 40
" "	12^{00} a. m.	" 44′	15°58′	25°9	" 30
" "	8^{30} p. m.	" 51′	" 19′	21°93	" 01
" "	11^{00} a. m.	Taormina Bay		21°10	" 08
20/8 "	8^{00} p. m.	38°07	15°35′	23 5	" 30
21/8 "	1^{00} a. m.	" 15	" 39′	25°06	" 01
" "	7^{00} a. m.	" 33	" 29′	25°4	37,92
" "	3^{00} p. m.	39°02	14°55′	26°0	38,03
" "	11^{00} p. m.	" 41	" 43′	25°4	37,97
22/8 "	2^{50} a. m.	" 59	" 31′	25°25	38,06
" "	7^{00} a. m.	40°27	" 19′	24°7	" 03
24/8 "	8^{30} p. m.	" 34	13°36′	23°9	37,95
25/8 "	2^{30} a. m.	" 22	" 02′	23°82	38,03
" "	7^{00} a. m.	" 08	12°26′	24°2	" 06
" "	11^{15} a. m.	39°55	11°51′	23°78	" 30
" "	6^{00} p. m.	" 32	10°49′	24°93	" 24
26/8 "	4^{05} a. m.	" 18	" 11′	24°05	" 21
" "	3^{15} p. m.	38°59	9°25′	24°5	" 21
" "	9^{30} p. m.	" 49	8°41′	24°1	" 21
27/8 "	2^{10} a. m.	" 52	" 11′	23°6	" 19
" "	6^{45} a. m.	" "	7°43′	23°5	" 19
" "	2^{00} p. m.	39°01	6°44′	24°7	37,09
" "	6^{00} p. m.	" 11	" 08′	24°68	" 25
28/8 "	4^{45} a. m.	" 32	5°15′	24°9	" 39
" "	3^{00} p. m.	" 43	4°30′	25°02	" 52
29/8 "	2^{20} a. m.	40°18	3°20′	24°0	38,15
" "	9^{30} a. m.	" 34	" 03′	24°5	" 10
" "	9^{45} p. m.	" 56	2°38′	23°88	" 01
30/8 "	0^{20} a. m.	41°10	" 23′	24°0	37,90
" "	8^{00} p. m.	40°55	1°44′	24°3	38,01
" "	12^{00} p. m.	" 33	" 18′	24°7	37,86
31/8 "	12^{00} a. m	39°39	0°39′	24°55	" 79
1/9 "	2^{00} a. m.	38°51	" 06′	25°2	" 43
" "	5^{30} a. m.	" 31	" 24′	25 02	" 32
1/9 "	0^{10} p. m.	" 01	" 48′	24 8	36,89
" "	6^{30} p. m.	37°37	2°12′	25°2	37,10
" "	10^{30} p. m.	" 15	" 35′	24°4	" 05
2/9 "	0^{15} a. m.	" 04	" 47′	23°76	36,80
3/9 "	3^{45} p. m.	36°45	" 20	22°9	" 78

te	Hour	Lat. N.	Long.	$t°$	$S‰$
10	7^{35} p. m.	36°40′	1°49′ E	23°7	36,76
"	11^{45} p. m	" 32′	" 07′	20°9	" 64
"	2^{30} a. m.	" 25′	0°42′	18°84	" 56
"	6^{30} a. m.	" 15′	" 08′	19°7	" 47
"	6^{45} p. m.	35°44′	0°53′ W	23°1	" 60
"	9^{15} p. m.	" 53′	" 57′	22°88	" 64
"	2^{00} a. m.	36°03′	1°12′	23°4	" 62
"	2^{30} p. m.	" 23′	" 44′	23°80	" 69
"	6^{00} p. m.	" 33′	2°00′	23°7	" 64
"	0^{20} a. m.	" 35′	" 35′	22°62	" 56
"	5^{30} a. m.	" 38′	3°13′	22°2	" 67
"	6^{30} p. m.	" 33′	4°25′	23°6	" 65
"	9^{10} p. m.	" 20′	" 45′	23°32	" 64
"	5^{00} a. m.	" 02′	5°06′	18°42	" 45
"	4^{00} p. m.	35°53′	6°40′	21°6	" 42
"	9^{20} a. m.	36°04′	7°51′	22°6	" 58
"	2^{30} p. m.	" 14′	8°26′	22°48	" 56
"	5^{05} a. m.	" 49′	9°15′	19°1	35,97
"	9^{40} a. m.	37°20′	" 17′	19°72	" 95
"	2^{30} p. m.	" 51′	" 19′	19°6	" 91
"	5^{25} a. m.	38°38′	" 25′	18°02	" 95
"	6^{00} p. m.	39°18′	" 25′	17°8	" 77
"	11^{30} p. m.	" 56′	" 26′	19°04	" 62
"	3^{15} a. m.	40°26′	" 26′	19°1	" 64
"	7^{30} a. m.	40°54′	9°28′	19°12	" 71
"	11^{40} a. m.	41°26′	" 30′	19°4	" 77
"	5^{40} p. m	" 56′	" 30′	19°38	" 77
"	11^{30} p. m.	42°30′	" 25′	14°1	" 70
"	2^{15} a. m.	" 46′	" 16′	14°35	" 64
"	5^{30} a. m.	43°02′	" 25′	14°4	" 66
"	10^{00} a. m.	" 31′	" 06′	13°61	" 61
"	2^{20} p. m.	" 57′	8°46′	14°3	" 50
"	10^{00} p. m.	44°34′	" 16′	17°34	" 57
"	3^{00} a. m.	45°00′	7 55′	17°5	" 55
"	7^{10} a. m.	" 26′	" 33′	17°73	" 55
"	11^{30} a. m.	" 52′	" 12′	17°0	" 61
"	4^{00} p. m.	46°43′	6°28′	17°2	" 41
"	2^{00} a. m.	47°32′	5°42′	16°1	" 43
"	8^{45} a. m.	48°02′	" 23′	14°6	" 26
"	9^{00} p. m.	" 43′	4°45′	12°8	" 25
"	3^{00} a. m.	49°00′	" 08′	14°20	" 25
"	10^{45} a. m.	" 18′	3°30′	14°88	" 01
"	4^{00} p. m.	" 36′	" 07′	15°0	" 08
"	9^{00} p. m.	" 52′	2°20′	15°12	34,92
"	4^{00} a. m.	50°11′	1°46′	15°05	35,10
"	9^{00} a. m.	" 28′	0°55′	15° 2	34,97
"	2^{30} p. m.	" 40′	0°15′ E	15°48	" 87

b) by Danish merchant vessels.

S/S "Siam", Copenhagen—Port Saïd.
Observer: Johs. Schmidt.

0 99	?	42°30′	9°25′ W	18°8	35,88
0 "	10^{30} a.m.	36°28′	7°26′	20°4	36,36
0 "	3^{00} p.m.	" 32′	2°00′	23°4	37,23
1 "	1^{30} p.m.	37°14′	8°02′ E	23°4	" 55
1 "	1^{30} p.m.	35°26′	17°18′	22°8	38,28
1 "	10^{00} a.m.	31°47′	30°27′	23°6	" 96
1 "	10^{00} a.m.	25°15′	35°26′	26°6	40,32

S/S "Siam", Port Saïd—Copenhagen.
Observer: 1st Officer.

00	7^{30} a.m.	26°55′	34°35′ E	22°3	40,26
"	11^{00} a.m.	32°40′	29°20′	16°8	38,43
"	8^{00} a.m.	38°25′	15°35′	14°1	37,61
"	8^{00} a.m.	42°00′	7°20′	12°95	38,09
"	7^{00} p.m.	41°00′	2°55′	12°8	" 08
"	5^{00} p.m.	36°41′	" 40′	14°6	37,06
"	7^{00} a.m.	" 57′	8°56′	15°0	36,25
"	12^{00} p.m.	44°15′	" 35′	12°1	35,62

S/S "Cathay", Port Saïd—Copenhagen.
Observer: Johs. Schmidt.

00	2^{30} p.m.	26°00′	35°08′ E	25°0	39,97
"	2^{30} p.m.	32°16′	29°45′	19°8	38,62

Date	Hour	Lat. N.	Long.	$t°$	$S‰$
$18/_5$ 00	6^{30} p.m.	26°24′	17°01′ E	19°0	37,76
$18/_5$ "	10^{30} p.m.	37°12′	8°18′	17°0	37,12
$21/_5$ "	1^{00} p.m.	36°20′	2°26′ W	17°3	36,93
$23/_5$ "	10^{00} p.m.	" 36′	8°00′	17°3	" 34
$25/_5$ "	4^{30} p.m.	44°03′	" 40′	14°4	35,76

S/S "Pangan", Gibraltar—Port Saïd.
Observer: H. Jacobsen, 1st Officer.

$24/_9$ 09	12^{00} a.m.	36°18′	2°45′ W	20°4	36,71
" "	5^{00} p.m.	" 24′	1°40′	21°0	" 74
" "	10^{00} p.m.	" 32′	0°38′	21°3	37,05
$25/_9$ "	4^{00} a.m.	" 40′	" 35′ E	21°6	36,71
" "	10^{00} a.m.	" 45′	1°48′	22°0	" 82
" "	4^{00} p.m.	" 50′	3°04′	23°0	" 91
" "	10^{00} p.m.	37°00′	4°17′	22°8	37,00
$26/_9$ "	4^{00} a.m.	" 05′	5°35′	23°0	" 09
" "	9^{00} a.m.	" 09′	6°39′	23°0	" 12
" "	1^{00} p.m.	" 13′	7°31′	23°3	" 50
" "	5^{00} p.m.	" 16′	8°26′	22°6	
" "	10^{00} p.m.	" 22′	9°37′	23°1	37,23
$27/_9$ "	4^{00} a.m.	" 10′	11°00′	23°0	" 56
" "	8^{00} a.m.	36°56′	" 51′	22°8	" 63
" "	12^{00} a.m.	" 40′	12°36′	22°7	" 83
" "	4^{00} p.m.	" 26′	13°28′	23°4	
" "	8^{00} p.m.	" 09′	14°20′	23°3	37,75
" "	12^{00} p.m.	35°52′	15°17′	24°6	38,31
$28/_9$ "	4^{00} a.m.	" 44′	16°08′	24°9	" 83
" "	8^{00} a.m.	" 33′	17°06′	24°3	" 12
" "	12^{00} a.m.	" 18′	" 50′	24°5	
" "	4^{00} p.m.	" 06′	18°38′	25°1	38,87
" "	8^{00} p.m.	34°55′	19°28′	24°7	" 69
" "	12^{00} p.m.	" 42′	20°24′	25°0	" 95
$29/_9$ "	4^{00} a.m.	" 28′	21°15′	25°3	" 96
" "	8^{00} a.m.	" 16′	22°03′	25°1	" 91
" "	12^{00} a.m.	" 02′	" 50′	25°1	" 84
" "	4^{00} p.m.	33°49′	23°41′	24°6	39,07
" "	8^{00} p.m.	" 34′	24°32′	24°7	" 42
" "	12^{00} p.m.	" 20′	25°23′	24°7	" 22
$30/_9$ "	4^{00} a.m.	" 05′	26°16′	24°9	" 18
" "	8^{00} a.m.	32°20′	27°02′	24°8	" 07
" "	12^{00} a.m.	" 34′	" 48′	25°7	" 23
" "	4^{00} p.m.	" 18′	28°32′	25°5	" 29
" "	8^{00} p.m.	" 10′	29°18′	25°0	" 40
" "	12^{00} p.m.	31°58′	30°12′	25°5	" 18
$1/_{10}$ "	4^{00} a.m.	" 50′	31°02′	25°9	37,65
" "	6^{00} a.m.	" 46′	" 26′	25°8	" 66
" "	8^{00} a.m.	" 39′	" 53′	25°9	25,88
" "	10^{00} a.m.	" 26′	32°11′	26°7	28,21

S/S "Arno", Ligurian Sea.
Observers: { Thomsen, 1st Officer. / Køhler, 2nd —

$25/_9$ 09	6^{00} a.m.	42°44′	6°17′ E	20°3	38,08
" "	8^{00} a.m.	42°54′	" 42′	20°5	" 03
" "	10^{00} a.m.	43°07′	" 58′	21°0	" 08
" "	12^{00} a.m.	" 17′	7°20′	21°3	" 15
" "	2^{00} p.m.	" 29′	" 40′	21°3	" 10
" "	4^{00} p.m.	" 41′	8°02′	21°4	" 01
" "	6^{00} p.m.	" 54′	" 19′	21°4	37,77
" "	8^{00} p.m.	44°04′	" 40′	21°0	38,12
$28/_9$ "	10^{00} p.m.	" 11′	9°14′	20°5	" 01
" "	12^{00} p.m.	43°53′	" 38′	20°5	" 12
$29/_9$ "	2^{00} a.m.	" 44′	" 52′	20°5	" 03

S/S "Arno", Messina—Bari.
Observers: { Thomsen, 1st Officer. / Køhler, 2nd —

$6/_{10}$ 09	6^{00} a.m.	39°20′	18°20′ E	22°0	38,01
" "	8^{00} a.m.	" 33′	" 32′	22°5	" 01
" "	10^{00} a.m.	" 58′	" 45′	22°8	37,77
" "	12^{00} a.m.	40°12′	" 50′	23°0	" 83
" "	2^{00} p.m.	" 33′	" 38′	23°0	" 72
" "	3^{00} p.m.	" 40′	" 19′	22°5	" 65
" "	6^{00} p.m.	" 52′	" 00′	22°2	" 47
" "	8^{00} p.m.	41°03′	17°40′	22°0	" 70
" "	10^{00} p.m.	" 14′	" 25′	21°8	" 30

Date	Hour	Lat. N.	Long.	$t°$	$S‰$
S/S "Pangan", Gibraltar—Port Saïd. Observer: H. Jacobsen, 1st Officer.					
$2/_2$ 10	5^{00} a.m.	36°15′	3°40′ W	13°5	37,70
" "	10^{00} a.m.	" 22′	2°27′	14°7	36,82
" "	2^{00} p.m.	" 28′	1°39′	15°0	" 71
" "	6^{00} p.m.	" 34′	0°48′	15°1	" 73
" "	10^{00} p.m.	" 39′	0°07′ E	14°5	" 74
$3/_2$ "	4^{00} a.m.	" 44	1°20′	15°0	" 96
" "	9^{00} a.m.	" 50′	2°43′	14°7	" 69
" "	1^{00} p.m.	" 54′	3°27′	14°6	" 64
" "	5^{00} p.m.	37°00′	4°22′	14°8	" 85
" "	10^{00} p.m.	" 11′	5°27′	14°5	" 43
$4/_2$ "	4^{00} a.m.	" 17′	6°46′	15°5	" 80
" "	9^{00} a.m.	" 14′	7°53′	14°7	" 89
" "	1^{00} p.m.	" 13′	8°40′	14°6	" 96
" "	5^{00} p.m.	" 22′	9°32′	14°7	37,07
" "	10^{00} p.m.	" 18′	10°49′	14°7	" 05
$5/_2$ "	4^{00} a.m.	36°59′	12°00′	14°7	" 27
" "	9^{00} a.m.	" 43′	13°01′	14°7	" 65
" "	1^{00} p.m.	" 32′	" 46′	14°7	" 52
" "	5^{00} p.m.	" 20′	14°32′	14°8	" 84
" "	10^{00} p.m.	" 05′	15°32′	14°5	38,01
$6/_2$ "	4^{00} a.m.	35°48′	16°40′	14°7	" 13
" "	9^{00} a.m.	" 34′	17°42′	14°8	" 17
" "	1^{00} p.m.	" 21′	18°30′	15°0	" 24
" "	4^{00} p.m.	" 12′	19°05′	14°9	" 31
" "	8^{00} p.m.	" 00′	" 50′	14°9	" 48
" "	12^{00} p.m.	34°48′	20°36′	15°0	" 57
$7/_2$ "	4^{00} a.m.	" 35′	21°22′	15°2	" 49
" "	8^{00} a.m.	" 18′	22°20′	15°3	" 55
" "	12^{00} a.m.	" 02′	23°04′	15°5	" 40
" "	4^{00} p.m.	33°48′	" 50′	15°1	" 60
" "	8^{00} p.m.	" 37′	24°46′	17°0	" 57
" "	12^{00} p.m.	" 24′	25°22′	16°5	" 75
$8/_2$ "	4^{00} a.m.	" 12′	26°06′	15°7	" 87
" "	8^{00} a.m.	32°57′	27°04′	17°2	" 93
" "	12^{00} a.m.	" 46′	" 50′	17°7	" 95
" "	4^{00} p.m.	" 34′	28°35′	17°2	" 93
" "	8^{00} p.m.	" 23′	29°17′	17°0	" 93
" "	12^{00} p.m.	" 14′	30°02′	17°3	" 89
$9/_2$ "	4^{00} a.m.	" 07′	" 51′	17°6	" 91
" "	8^{06} a.m.	31°46′	32°00′	16°7	" 84

S/S "Arno", Gibraltar—Leghorn—Messina—Gibraltar.
Observers: { Thomsen, 1st Officer. / Køhler, 2nd —

$9/_3$ 10	8^{00} a.m.	36°50′	1°55′ W	14°0	37,57
" "	10^{00} a.m.	" "	" 38′	14°0	" 66
" "	12^{00} a.m.	37°05′	" 24′	14°5	" 41
" "	2^{00} p.m.	" 14′	" 03′	14°5	" 56
" "	4^{00} p.m.	" 30′	0°35′	14°5	" 66
" "	6^{00} p.m.	" 45′	" 30′	14°5	" 92
" "	8^{00} p.m.	38°00′	" 16′	14°5	" 29
" "	10^{00} p.m.	" 18′	" 00′	14°5	" 48
" "	12^{00} p.m.	" 31′	" 12′	14°0	" 39
$10/_3$ "	2^{00} a.m.	" 52′	" 28′	14°0	" 18
" "	4^{00} a.m.	39°12′	" 42′	14°0	" 18
" "	6^{00} a.m.	" 22′	" 50′	13°0	38,04
" "	8^{00} a.m.	" 37′	1°04′	13°0	" 08
" "	10^{00} a.m.	" 50′	" 27′	13°0	" 19
" "	12^{00} a.m.	40°02′	" 40′	13°0	37,95
" "	2^{00} p.m.	" 20′	" 55′	13°0	38,21
" "	4^{00} p.m.	" 35′	2°10′	13°0	" 31
" "	6^{00} p.m.	" 49′	" 24′	13°0	" 31
" "	8^{00} p.m.	41°05′	" 45	13°0	" 22
" "	10^{00} p.m.	" 14′	3°05′	13°0	" 40
" "	12^{00} p.m.	" 23′	" 21′	13°0	" 40
$11/_3$ "	2^{00} a.m.	" 32′	" 44′	12°5	" 42
" "	4^{00} a.m.	" 43′	4°00′	12°5	" 24
" "	6^{00} a.m.	" 53′	" 21′	12°5	" 28
" "	8^{00} a.m.	42°04′	" 40′	12°5	" 37
" "	10^{00} a.m.	" 10′	5°00′	12°5	" 37
" "	12^{00} a.m.	" 13′	" 14′	12°5	" 42
" "	2^{00} p.m.	" 18′	" 37′	13°0	" 46

Date	Hour	Lat.N.	Long.	$t°$	$S‰$
11/8 10	4⁰⁰ p. m.	42°25′	6°00′ E	13°0	38,44
" "	6⁰⁰ p. m.	" 31′	" 18′	13°0	" "
" "	8⁰⁰ p. m.	" 33′	" 66′	13°0	" 46
" "	10⁰⁰ p. m.	" 40′	7°05′	13°0	" 44
" "	12⁰⁰ p. m.	" 49′	" 25′	13°0	" 42
12/8 "	2⁰⁰ a. m.	" 52′	" 41′	13°0	" 37
" "	4⁰⁰ a. m.	" 55′	8°15′	13°0	" 35
" "	6⁰⁰ a. m.	43°00′	" 35′	13°0	" 12
" "	8⁰⁰ a. m.	" 03′	" 58′	13°0	" 17
" "	10⁰⁰ a. m.	" 13′	9°20′	13°0	" 10
" "	12⁰⁰ a. m.	" 18′	" 40′	13°0	" 19
" "	2⁰⁰ a. m.	" 30′	" 55′	13°0	" 19
19/8 "	10⁰⁰ p. m.	44°10′	" 10′	13°0	
" "	12⁰⁰ p. m.	43°57′	" 27′	13°0	38,10
20/8 "	4⁰⁰ a. m.	" 33′	10°05′	13°0	" 10
" "	8⁰⁰ a. m.	42°55′	" 25′	13°0	" 10
" "	12⁰⁰ a. m.	" 30′	" 53′	14°0	" 04
" "	4⁰⁰ p. m.	" 00′	11°30′	14°5	" 10
" "	8⁰⁰ p. m.	41°30′	12°00′	14°5	" 06
" "	12⁰⁰ p. m.	" 05′	" 28′	14°0	" 10
21/8 "	4⁰⁰ a. m.	40°45′	13°05′	13°5	" 04
" "	8⁰⁰ a. m.	" 40′	" 50′	13°5	" 04
22/8 "	4⁰⁰ p. m.	" 30′	14°20′	14°5	37,94
" "	8⁰⁰ p. m.	39°54′	" 14′	14°0	" 90
" "	12⁰⁰ p. m.	" 17′	15°04′	14°0	38,06
23/8 "	4⁰⁰ a. m.	38°45′	" 25′	14°0	37,72
" "	8⁰⁰ a. m.	" 20′	" 40′	14°0	" 74
26/8 "	12⁰⁰ p. m.	" 18′	" 10′	13°5	" 66
27/8 "	4⁰⁰ a. m.	" 14′	14°17′	13°5	" 94
" "	8⁰⁰ a. m.	" 12′	13°25′	13°5	" 54
30/8 "	12⁰⁰ a. m.	" 20′	12°52′	14°0	" 43
" "	4⁰⁰ p. m.	" 23′	" 10′	14°0	" 54
" "	8⁰⁰ p. m.	" 27′	11°17′	14°0	" 23
" "	12⁰⁰ p. m.	" 31′	10°35′	14°0	" 56
31/8 "	4⁰⁰ a. m.	" 34′	9°45′	13°5	38,22
" "	8⁰⁰ a. m.	" 37′	8°55′	13°5	" 10
" "	12⁰⁰ a. m.	" 23′	" 20′	14°0	37,77
" "	4⁰⁰ p. m.	" 19′	7°40′	14°5	" 03
" "	8⁰⁰ p. m.	" 12′	6°52′	14°0	" 16
" "	12⁰⁰ p. m.	" 06′	" 10′	14°0	36,87
1/4 "	4⁰⁰ a. m.	37°54′	5°22′	14°5	" 94
" "	8⁰⁰ a. m.	" 49′	4°25′	14°5	37,18
" "	12⁰⁰ a. m.	" 39′	3°35′	14°5	" 05
" "	4⁰⁰ p. m.	" 31′	2°54′	14°5	" 50
" "	8⁰⁰ p. m.	" 23′	" 14′	14°0	" 43

S/S "Pangan", Port Saïd—Gibraltar.
Observer: H. Jacobsen, 1st Officer.

24/4 10	1⁰⁰ p. m.	32°14′	30°06′ E	18°1	38,77
" "	5⁰⁰ p. m.	" 26′	29°18′	17°9	" 78
" "	10⁰⁰ p. m.	" 42′	28°21′	17°4	" 78
25/5 "	4⁰⁰ a. m.	33°04′	27°02′	17°0	" 75
" "	9⁰⁰ a. m.	" 19′	26°02′	17°0	" 75
" "	1⁰⁰ p. m.	" 32′	25°19′	17°2	" 73
" "	5⁰⁰ p. m.	" 45′	24°26′	17°2	" 69
" "	10⁰⁰ p. m.	34°00′	23°28′	17°2	" 57
26/5 "	4⁰⁰ a. m.	" 22′	22°13′	16°8	" 58
" "	9⁰⁰ a. m.	" 40′	21°08′	17°0	" 57
" "	2⁰⁰ p. m.	" 56′	20°11′	17°0	" 60
" "	6⁰⁰ p. m.	35°06′	19°12′	16°6	" 24
" "	10⁰⁰ p. m.	" 14′	18°33′	16°3	" 26
27/4 "	4⁰⁰ a. m.	" 28′	17°20′	16°2	" 06
" "	9⁰⁰ a. m.	" 42′	16°20′	16°4	37,95
" "	1⁰⁰ p. m.	" 54′	15°34′	16°7	" 13
" "	5⁰⁰ p. m.	" 58′	14°36′	16°7	" 68
" "	10⁰⁰ p. m.	36°20′	13°36′	15°7	" 70
28/4 "	2⁰⁰ a. m.	" 36′	12°50′	15°7	" 27
" "	6⁰⁰ a. m.	" 52′	" 01′	15°5	" 23
" "	10⁰⁰ a. m.	37°05′	11°04′	15°5	" 03
" "	2⁰⁰ p. m.	" 17′	10°14′	15°6	36,98
" "	6⁰⁰ p. m.	" 32′	9°26′	15°4	37,29
" "	10⁰⁰ p. m.	" 36′	8°38′	14°7	" 57
29/4 "	2⁰⁰ a. m.	" 33′	7°44′	14°2	" 66
" "	6⁰⁰ a. m.	" 28′	6°54′	15°6	36,85
" "	10⁰⁰ a. m.	" 25′	" 02′	16°4	37,18

Date	Hour	Lat.N.	Long.	$t°$	$S‰$
29/4 10	2⁰⁰ p. m.	37°21′	5°08′ E	17°0	36,85
" "	6⁰⁰ p. m.	" 16′	4°22′	16°5	" 71
" "	10⁰⁰ p. m.	" 12′	3°28′	16°3	37,12
30/4 "	2⁰⁰ a. m.	" 06′	2°28′	16°5	" 19
" "	7⁰⁰ a. m.	36°58′	1°26′	16°8	36,67
" "	12⁰⁰ a. m.	" 50′	0°18′	16°7	" 85
" "	5⁰⁰ p. m.	" 44′	0°44′ W	16°5	" 92
" "	10⁰⁰ p. m.	" 38′	1°52′	16°1	37,34
1/5 "	2⁰⁰ a. m.	" 33′	2°40′	15°7	" 00
" "	6⁰⁰ a. m.	" 28′	3°30′	15°0	36,92
" "	10⁰⁰ a. m.	" 36′	4°21′	15°3	" 26
" "	2⁰⁰ p. m.	" 22′	5°18′	15°2	37,79

S/S "Pangan", Gibraltar—Genoa—Port Saïd.

23/6 10	6⁰⁰ p. m.	36°07′	4°32′ W	19°3	36,38
" "	12⁰⁰ p. m.	" 21′	3°26′	20°2	" 31
24/6 "	6⁰⁰ a. m.	" 46′	1°51′	21°5	37,03
" "	12⁰⁰ a. m.	37°23′	0°56′	21°8	" 75
" "	6⁰⁰ p. m.	38°04′	0°06′	22°0	
" "	12⁰⁰ p. m.	" 52′	0°50′	21°1	37,41
25/6 "	6⁰⁰ a. m.	39°38′	1°51′ E	20°4	38,04
" "	12⁰⁰ a. m.	40°22′	2°52′	21°6	" 19
" "	6⁰⁰ p. m.	41°05′	3°58′	20°3	37,95
" "	12⁰⁰ p. m.	" 56′	5°06′	18°3	38,24
26/6 "	6⁰⁰ a. m.	42°30′	" 56′	19°0	37,97
" "	12⁰⁰ a. m.	43°17′	6°55′	20°0	" 83
" "	6⁰⁰ p. m.	" 48′	8°08′	19°3	" 95
" "	12⁰⁰ p. m.	44°06′	" 48′	18°7	" 75
28/6 "	12⁰⁰ p. m.	43°47′	9°33′	20°0	
29/6 "	6⁰⁰ a. m.	" 02′	10°20′	21°7	37,45
" "	12⁰⁰ a. m.	42°12′	11°15′	21°2	38,17
" "	6⁰⁰ p. m.	41°16′	12°15′	21°8	37,83
" "	12⁰⁰ p. m.	40°35′	" 58′	21°7	" 86
30/6 "	6⁰⁰ a. m.	38°48′	13°54′	22°3	" 94
" "	2⁰⁰ p. m.	38°55′	14°58′	24°5	" 97
" "	10⁰⁰ p. m.	37°47′	16°00′	22°0	38,33
1/7 "	5⁰⁰ a. m.	" 14′	17°34′	22°6	" 24
" "	12⁰⁰ a. m.	36°47′	18°51′	23°5	" 39
" "	5⁰⁰ p. m.	" 24′	19°50′	23°0	" 60
" "	10⁰⁰ p. m.	" 02′	20°48′	22°8	" 46
2/7 "	4⁰⁰ a. m.	35°33′	22°00′	22°5	" 46
" "	8⁰⁰ a. m.	" 16′	" 45′	22°3	" 66
" "	1⁰⁰ p. m.	34°52′	23°38′	22°0	" 75
" "	5⁰⁰ p. m.	" 36′	24°22′	22°8	39,05
" "	9⁰⁰ p. m.	" 19′	25°05′	22°5	38,96
3/7 "	1⁰⁰ a. m.	" 00′	" 52′	22°6	" 84
" "	5⁰⁰ a. m.	33°43′	26°39′	23°2	" 93
" "	9⁰⁰ a. m.	" 20′	27°30′	23°0	" 96
" "	1⁰⁰ p. m.	" 01′	28°16′	23°5	" 93
" "	5⁰⁰ p. m.	32°46′	29°00′	23°0	
" "	9⁰⁰ p. m.	" 30′	" 40′	23°5	38,93
4/7 "	1⁰⁰ a. m.	" 12′	30°41′	23°3	" 93
" "	5⁰⁰ a. m.	31°58′	31°28′	23°7	" 96
" "	9⁰⁰ a. m.	" 32′	32°07	25°5	" 98

S/S "Pangan", Port Saïd—Gibraltar.
Observer: H. Jacobsen, 1st Officer.

15/9 10	4⁰⁰ p. m.	31°34′	32°00′ E		33,68
" "	10⁰⁰ p. m.	31°56′	30°52′		39,00
16/9 "	4⁰⁰ a. m.	32°12′	29°51′		39,24
" "	8⁰⁰ a. m.	32°22′	29°12′		39,36
" "	1⁰⁰ p. m.	32°33,	28°14′		39,31
" "	4⁰⁰ p. m.	32°46′	27°28′		39,33
" "	10⁰⁰ p. m.	33°00′	26°30′		39,29
17/9 "	4⁰⁰ a. m.	33°18′	25°12′		39,00
" "	8⁰⁰ a. m.	33°28′	24°26′		38,95
" "	12⁰⁰ a. m.	33°42′	23°28′		39,00
" "	5⁰⁰ p. m.	33°58′	22°28′		38,86
" "	10⁰⁰ p. m.	34°15′	21°30′		38,93
18/9 "	4⁰⁰ a. m.	34°30′	20°12,		38,84
" "	8⁰⁰ a. m.	34°38′	19°34′		38,61
" "	12⁰⁰ a. m.	34°49′	18°42′		38,64
" "	5⁰⁰ p. m.	35°08′	17°44′		38,17
" "	10⁰⁰ p. m.	35°26′	16°47′		37,90

Date	Hour	Lat.N.	Long.	$t°$	$S‰$
19/9 10	4⁰⁰ a. m.	35°48′	15°36′ E		37,85
" "	8⁰⁰ a. m.	36°03′	14°42′		37,61
" "	12⁰⁰ a. m.	36°18′	13°50′		37,70
" "	5⁰⁰ p. m.	36°37′	12°57′		37,76
" "	10⁰⁰ p. m.	36°55′	11°53′		37,47
20/9 "	4⁰⁰ a. m.	37°17′	10°43′		37,43
" "	8⁰⁰ a. m.	37°28′	9°53′		37,47
" "	1⁰⁰ p. m.	37°30′	8°48′		37,56
" "	5⁰⁰ p. m.	37°26′	7°58′		37,31
" "	10⁰⁰ p. m.	37°20′	6°49′		37,49
21/9 "	4⁰⁰ a. m.	37°13′	5°35′		36,73
" "	8⁰⁰ a. m.	37°09′	4°41′		37,16
" "	12⁰⁰ a. m.	37°07′	3°49′		37,07
" "	6⁰⁰ p. m.	37°03′	2°40′		36,87
" "	10⁰⁰ p. m.	37°00′	1°49′		36,75
22/9 "	5⁰⁰ a. m.	36°49′	0°20′		37,23
" "	9⁰⁰ a. m.	36°44′	0°38′ W		37,25
" "	12⁰⁰ a. m.	36°43′	1°18′		37,25
" "	6⁰⁰ p. m.	36°35′	2°29′		36,69
" "	10⁰⁰ p. m.	36°32′	3°29′		36,60
23/9 "	2⁰⁰ a. m.	36°21′	4°07′		36,62
" "	5⁰⁰ a. m.	36°15′	4°42′		36,60
" "	11⁰⁰ a. m.	36°04′	5°58′		36,31

S/S "Pangan", Gibraltar—Genoa—Port Saïd.

9/8 11	3³⁰ p. m.	39°07′	1°14′ E	27°0	37,10
10/8 "	9⁰⁰ p. m.	" 42′	2°10′	27°0	" 83
20/8 "	2⁰⁰ a. m.	40°20′	3°05′	26°5	" 86
" "	1⁰⁰ p. m.	41°28	4°42′	25°5	" 86
" "	6⁰⁰ p. m.	42°04′	5°40′	23°5	38,22
" "	11⁰⁰ p. m.	" 35′	6°35′	25°0	" 08
21/8 "	4⁰⁰ a. m.	43°14′	7°25′	25°5	" 31
" "	9⁰⁰ a. m.	" 53′	8°08′	26°3	" 03
" "	2¹⁵ p. m.	44°23′	"°53′	26°5	" 04
26/8 "	9⁰⁰ p. m.	35°50′	21°30′	27°5	" 80
27/8 "	11⁰⁰ p. m.	34°50′	26°20′	26°3	39,29

c) by Foreign merchant vessels.

S/S "Kleist", Algiers—Genoa.
Observer: A. Schulze, 3rd Officer.

8/2 10	8⁰⁰ a. m.	37°33′	3°25′ E	14°1	37,27
" "	10⁰⁰ a. m.	38°03′	" 27′	13°8	" 59
" "	12⁰⁰ a. m.	" 31′	" 48′	13°8	" 47
" "	2⁰⁰ p. m.	" 57′	" 58′	13°6	" 83
" "	4⁰⁰ p. m.	39°25′	4°10′	13°5	" 90
" "	8⁰⁰ p. m.	40°16′	" 45′	13°2	" 79
" "	10⁰⁰ p. m.	" 42′	5°05′	12°3	38,17
" "	12⁰⁰ p. m.	41°04′	" 20′	12°4	" 04
9/2 "	2⁰⁰ a. m.	" 20′	" 40′	10°2	" 15
" "	4⁰⁰ a. m.	" 36′	" 53′	10°0	" 06

S/S "Prinz Ludwig", Algiers—Genoa.
Observer: Paul König, 1st Officer.

21/2 10	2⁰⁰ a. m.	37°20′	3°19′ E	14°3	36,91
" "	4⁰⁰ a. m.	" 47′	" 31′	13°9	37,16
" "	6⁰⁰ a. m.	38°09′	" 43′	13°8	" 63
" "	8⁰⁰ a. m.	" 36′	" 54′	13°9	" 63
" "	10⁰⁰ a. m.	39°03′	4°07′	13°2	" 86
" "	12⁰⁰ a. m.	" 31′	" 21′	13°0	" 92
" "	2⁰⁰ p. m.	" 57′	" 41′	14°0	" 70
" "	4⁰⁰ p. m.	40°22′	5°01′	13°3	38,06
" "	6⁰⁰ p. m.	" 48′	" 20′	13°0	" 06
" "	8⁰⁰ p. m.	41°12′	" 40′	14°0	" 21

S/S "Charles Roux", Marseilles—Algiers.

23/2 10	8⁰⁰ p. m.	41°47′	4°53′ E	15°0	38,30
24/2 "	2⁰⁰ a. m.	39°29′	" 14′	13°5	37,88
" "	4⁰⁰ a. m.	38°55′	3°59′	13°75	" 36
" "	5⁰⁰ a. m.	" 20′	" 49′	14°0	" 32
" "	8⁰⁰ a. m.	37°45′	" 32′	14°0	38,13
" "	10⁰⁰ a. m.	" 20′	" 20′	14°25	" 30

ıate	Hour	Lat.N.	Long.	$t°$	$S‰$

S/S "Gneisenau", Algiers—Genoa
Observer: J. Preuss.

/8 10	6⁰⁰ p.m.	37°06′	3°19′ E	14°8	36,74
„	8⁰⁰ p.m.	„ 31′	„ 38′	14°4	37,16
„	10⁰⁰ p.m.	„ 55′	„ 55′	14°4	„ 50
„	12⁰⁰ p.m.	38°20′	4°14′	13°9	„ 03
/9 „	2⁰⁰ a.m.	„ 44′	„ 31′	13°8	„ 72
„	4⁰⁰ a.m.	39°06′	„ 47′	13°2	„ 81
„	6⁰⁰ a.m.	„ 30′	5°04′	12°8	„ 79
„	8⁰⁰ a.m.	„ 52′	„ 21′	13°0	„ 66
„	10⁰⁰ a.m.	40°14′	„ 37′	12°7	„ 94
„	12⁰⁰ a.m.	„ 37′	„ 55′	12°7	38,28

S/S "Charles Roux", Marseilles—Algiers.

/8 10	2⁰⁰ p.m.	43°04′	5°14′ E	14°2	38°22
„	4⁰⁰ p.m.	42°29′	„ 03′	13°75	„ 15
„	6⁰⁰ p.m.	41°52′	4°54′	14°0	„ 15
„	8⁰⁰ p.m.	„ 17′	„ 44′	14°2	„ 13
„	11⁰⁰ p.m.	40°30′	„ 32′	13°75	37°79
/8 „	1⁸⁰ a.m.	39°46,	„ 20′	13°25	„ 92
„	3⁰⁰ a.m.	„ 16′	„ 10′	13°75	„ 27
„	5⁰⁰ a.m.	38°42′	3°55′	14°5	„ 25
„	7⁰⁰ a.m.	„ 08′	„ 40′	14°75	„ 27

S/S "Charles Roux", Algiers—Marseilles.

/8 10	2⁰⁰ p.m	37°01′	3°13′ E	14°25	37,05
„	4⁰⁰ p.m	„ 35′	„ 28′	14°5	36,82
„	6⁰⁰ p.m	38°09′	„ 45′	13°75	37,92
„	8⁰⁰ p.m	„ 42′	4°03′	13°0	„ 90
„	10⁰⁰ p.m	39°20′	„ 20′	13°3	„ 83
„	12⁰⁰ p.m	40°09′	„ 32′	13°0	„ 83
/8 „	2⁰⁰ a.m	„ 42,	„ 40′	13°0	„ 90
„	4⁰⁰ a.m	41°16′	„ 48′	13°25	38,22
„	6⁰⁰ a.m	„ 49′	„ 56′	13°25	„ 22
„	8⁰⁰ a.m	42°21′	5°04′	14°0	„ 22
„	10⁰⁰ a.m	„ 55′	„ 13′	14°5	„ 28

S/S "Charles Roux", Algiers—Marseilles.

/8 10	2⁰⁰ p.m.	37°10′	3° 16′E	15°0	37,18
„	4⁰⁰ p.m.	„ 44′	„ 32′	14°5	36,89
„	6⁰⁰ p.m.	38°18′	„ 44′	14°3	37,34
„	8⁰⁰ p.m.	„ 53′	4°00′	14°0	„ 70
„	10⁰⁰ p.m.	39°33′	„ 12′	14°0	„ 86
„	12⁰⁰ p.m.	40°06′	„ 27′	14°0	„ 84
/8 „	2⁰⁰ a.m.	„ 42′	„ 40′	13°5	38,12
/8 „	4⁰⁰ a.m.	41°19′	„ 49′	13°0	„ 19
„	6⁰⁰ a.m.	„ 54′	„ 58′	12°7	„ 30
„	8⁰⁰ a.m.	42°28′	5°05′	13°5	„ 40
„	10⁰⁰ a.m.	43°03′	„ 14′	13°5	„ 22

Date	Hour	Lat.N.	Long.	$t°$	$S‰$

S/S "Goeben", Algiers—Genoa.
Observer: W. Löding, 3rd officer.

7/8 10	10⁰⁰ p.m.	37°12′	3°22′ E	14°4	36,98
8/8 „	2⁰⁰ a.m.	38°03′	4°00′	14°8	37,16
„ „	6⁰⁰ a.m.	„ 53′	„ 34′	13°5	„ 45
„ „	9⁰⁰ a.m.	39°31′	5°00′	13°5	„ 65
„ „	11⁰⁰ a.m.	„ 56′	„ 21′	13°5	„ 72
„ „	1⁰⁰ p.m.	40°13′	„ 40′	13°7	„ 83
„ „	3⁰⁰ p.m.	„ 39′	„ 59′	13°6	38,08
„ „	5⁰⁰ p.m.	41°13′	6°18	13°1	„ 31
„ „	7⁰⁰ p.m.	„ 38′	„ 35′	13°5	„ 24
„ „	9⁰⁰ p.m.	42°02′	„ 53′	13°0	„ 30
„ „	11⁰⁰ p.m.	„ 28′	7°11	12°6	„ 24
9/8 „	1⁰⁰ a.m.	„ 49′	„ 29′	12°8	„ 42
„ „	3⁰⁰ a.m.	43°14′	„ 47′	12°6	„ 42
„ „	5⁰⁰ a.m.	„ 40′	8°08′	12°8	„ 44
„ „	7⁰⁰ a.m.	43°58′	„ 28′	12°6	„ 22

S/S "Prinz Eitel Friedrich", Genoa—Algiers.
Observer: Captain E. Malchow.

9/8 10	10⁰⁰ p.m.	43°23′	7°52′ E	13°0	38,44
„ „	12⁰⁰ p.m.	„ 01′	„ 27′	12°9	„ 42
10/8 „	2⁰⁰ a.m.	42°37′	„ 03′	12°9	„ 30
„ „	4⁰⁰ a.m.	„ 15′	6°40′	12°7	„ 15
„ „	6⁰⁰ a.m.	41°50′	„ 17′	12°8	„ 17
„ „	8⁰⁰ a.m.	„ 22′	5°48′	12°9	„ 15
„ „	10⁰⁰ a.m.	40°58′	„ 25′	13°2	37,83
„ „	0⁰⁰ p.m.	„ 30′	„ 01′	13°5	„ 81
„ „	2⁰⁰ p.m.	„ 05′	4°32′	13°7	„ 72
„ „	4⁰⁰ p.m.	39°43′	„ 26′	13°5	„ 74
„ „	6⁰⁰ p.m.	„ 14′	„ 14′	13°5	
„ „	8⁰⁰ p.m.	38°30′	3°55′	13°9	37,63
„ „	10⁰⁰ p.m.	„ 05′	„ 43′	14°1	„ 45
„ „	12⁰⁰ p.m.	37°40′	„ 32′	14°7	36,92
11/8 „	2⁰⁰ a.m.	„ 25′	„ 25′	14°5	37,16
„ „	4⁰⁰ a.m.	„ 10′	„ 18′	14°7	

S/S "Goeben", Messina—Port Saïd.
Observer: W. Löding, 3rd officer.

12/8 10	8⁰⁰ p.m.	37°23′	17°00′ E	14°3	38,19
„ „	12⁰⁰ p.m.	36°57′	18°05′	14°6	„ 21
13/8 „	4⁰⁰ a.m.	„ 32′	19°09′	14°1	„ 24
„ „	7⁰⁰ a.m.	„ 09′	20°06′	14°4	„ 39
13/8 „	12⁰⁰ a.m.	35°43′	21°05′	14°7	„ 60
„ „	4⁰⁰ p.m.	„ 18′	22°09′	14°5	„ 66
„ „	8⁰⁰ p.m.	34°52′	23°12′	14°8	„ 86
„ „	12⁰⁰ p.m.	„ 30′	24°15′	14°8	„ 66
14/8 „	4⁰⁰ a.m.	„ 08′	25°19′	14°8	„ 91
„ „	8⁰⁰ a.m.	33°48′	26°15′	14°8	„ 82
„ „	12⁰⁰ a.m.	„ 25′	27°18′	15°8	„ 58
„ „	4⁰⁰ p.m.	„ 03′	28°22′	16°4	„ 93

Date	Hour	Lat.N.	Long.	$t°$	$S‰$
14/8 10	8⁰⁰ p.m.	32°41′	29°26′ E	16°2	38,93
„ „	12⁰⁰ p.m.	„ 20′	30°30′	16°2	„ 87
15/8 „	4⁰⁰ a.m.	31°58′	31°34′	16°0	„ 82

S/S "Prinz Eitel Friedrich", Messina—Port Saïd.
Observer: Captain Malchow.

23/4 10	8¹⁵ p.m.	37°16′	17°29′ E	15°6	38,22
„ „	10⁰⁰ p.m.	„ 04′	18°01′	15°5	„ „
24/4 „	0⁰⁰ a.m.	36°50′	„ 30′	15°6	„ „
„ „	2⁰⁰ a.m.	„ 38′	19°00′	15°6	„ „
„ „	4⁰⁰ a.m.	„ 26′	„ 36′	15°5	„ „
„ „	6⁰⁰ a.m.	„ 15′	20°04′	15°4	„ 33
„ „	8⁰⁰ a.m.	„ 02′	„ 37′	15°5	„ 49
„ „	10⁰⁰ p.m.	35°49′	21°02′	16°0	„ 68
„ „	0⁰⁵ p.m.	„ 36′	„ 36′	16·0	„ 53
„ „	2⁰⁰ p.m.	„ 22′	22°09′	16°1	„ 66
„ „	4⁰⁰ p.m.	„ 11′	„ 42′	16°0	„ 80
„ „	6⁰⁰ p.m.	34°59′	23°16′	16°0	„ 80
„ „	8⁰⁰ p.m.	„ 46′	„ 47′	16°4	
„ „	10⁰⁰ p.m.	„ 37′	24°11′	16°3	38,68
25/4 „	0⁰⁰ a.m.	„ 26′	„ 42′	16°4	„ 80

S/S "Maria Theresa", Triest—Alexandria.
Observers: Dr. R. Koefoed and Dr. L. Brühl.

1/11 11	11⁵⁴ p.m.	42°29′	18°02′ E	19°46	38,15
2/11 „	3⁰⁰ a.m.	41°56′	„ 00′	18·50	„ 15
„ „	4³⁰ a.m.	„ 42′	„ 00′	17·90	„ 30
„ „	5⁵⁵ a.m.	„ 23′	„ 00′	18·00	37,94
„ „	9⁰⁰ a.m.	40°53′	„ 00′	18°10	
„ „	6³⁵ p.m.	„ 09′	„ 00′	18°40	37,34
„ „	11³⁰ p.m.	39°31′	19°28′	20°21	38,39
3/11 „	6¹⁵ a.m.	38°45′	20°23′	20·20	„ 49
„ „	2⁰⁵ p.m.	37°37′	21°06′	20°30	„ 55
„ „	9⁰⁵ p.m.	36°29′	„ 52′	21·20	„ 84
4/11 „	2¹⁰ p.m.	34°42′	24°25′	21°50	39,04
„ „	9⁰⁵ p.m.	33°58′	25°32′	18·25	„ 18
5/11 „	8¹⁵ a.m.	32°48′	27°32′	22°90	„ 05
„ „	1⁰⁵ p.m.	„ 13′	28°16′	22°95	„ 14

S/S "Goritia", Jaffa—Port Saïd—Triest.
Observer: Dr. R. Koefoed.

7/2 12	8²⁰ p.m.	31°55′	34°11′ E	17·05	38,86
14/2 „	8⁵⁰ a.m.	33°11′	26°42′	16°10	„ 35
„ „	2¹⁵ p.m.	33°50′	25·33′	16·10	„ 87
15/2 „	4⁴⁰ p.m.	36°49′	21°36′	14°90	„ 58
16/2 „	2⁸⁰ p.m.	38°49′	20°15′	14°70	„ 53
17/2 „	2⁵⁰ p.m.	41°54′	17°00′	12°90	„ 31

2.

Hydrography of the Mediterranean

and adjacent waters

by

J. N. Nielsen.

CONTENTS.

page

A. Review of Earlier Hydrographical Investigations in the Mediterranean ... 79
I. The period previous to 1870 ... 79
II. The period after 1870 ... 87
B. The "Thor" Expeditions in the Mediterranean ... 105
I. The temperature observations and water-samples ... 105
II. The salinity determinations ... 109
III. The Black Sea and Sea of Marmora ... 112
IV. The Aegean Sea ... 120
V. Eastern basin of the Mediterranean ... 123
1. Remarks on the diurnal range of temperature in the surface-layer ... 123
2. The distribution of temperature and salinity ... 125
3. The circulation in the eastern basin of the Mediterranean ... 132
a. Horizontal circulation ... 132
b. Vertical circulation ... 138
VI. The temperature at great depths ... 142
VII. Western basin of the Mediterranean ... 147
1. The vertical distribution of temperature and salinity ... 148
a. The Tyrrhenian Sea ... 148
b. The Balearic Sea and adjacent waters ... 150
2. The horizontal distribution of temperature and salinity and the horizontal circulation in the Western Mediterranean 151
a. The Tyrrhenian Sea ... 151
b. The Balearic Sea and adjacent waters ... 155
3. The vertical circulation in the Western Mediterranean ... 165
VIII. Exchange of water in the Mediterranean and the currents through the Straits of Gibraltar ... 170
IX. The influence of the outflowing Mediterranean water in the Atlantic Ocean ... 179
C. Résumé ... 183
I. Historical Summary ... 183
II. Results of the "Thor's" investigations in 1908—09 and 1910 ... 184
D. Bibliography ... 187

A. Review of Earlier Hydrographical Investigations in the Mediterranean.

I. The period previous to 1870.

Probably the first determination of the temperature of the Mediterranean water below the surface was that made by Count Marsilli in 1706—1707 [1725, p. 16] between Cassis and Riou in the neighbourhood of Marseilles. Regarding the manner of the observations, however, Marsilli gives but little information, simply that they were taken with a thermometer "dont la grandeur, et la division des degrez est marquée au dessein". With this instrument Marsilli carried on his observations from December 1706 to April 1707 and found that "la temperature à la profondeur de 10, 20, 30 et 120 Brasses étoit toûjours également de 10 degrez et demi, ou de $10^3/_4$," whilst the temperature of the surface varied from $8^1/_2°$ in January to 12° in March. To ascertain whether the same temperature occurred in the deeper water in summer, Marsilli repeated the observations in June but was interrupted by an enemy's brig and in the haste to get away the thermometer got broken, so that the observations were never completed. The two determinations made, however, in depths of 100 and 120 brasses (fathoms), gave the values 13° and 15° (at the surface the temperature was 15°), but Marsilli seems to have been disinclined to believe in the correctness of these observations and apparently held to the view that the temperature found in winter persists in the deeper layers of water throughout the whole year.

In this perhaps we have the origin of the view which has prevailed for almost 200 years, that the temperature is constant in the deeper water of the Mediterranean, but from Marsilli's remarks it is seen that he refers 10 brasses to the "deep water" in which the temperature was supposed to be constant. On the other hand, Marsilli has noted that just as on land the plant-life of the sea begins to grow strongly in the spring-time, and this would signify that the temperature must rise in the water below the surface, since the condition for the rejuvenescence of the land-vegetation is just the rise of temperature in the air.

As Marsilli does not give any detailed account of his thermometer and method of working, it is difficult to determine how far the observations noted really represent the relative values of the temperature in the depths mentioned. That the thermometer has not been particularly sensitive to changes of temperature may in all probability be taken for granted; but, in addition, if the thermometer, after registering the temperature at ca. 200 meters, has been hauled up through a layer of water with very different temperature from itself, it will undergo change on the way and this change will depend on the time taken in hauling up. Thus, Marsilli's discovery that the temperature is constant in winter, is undoubtedly correct and his finding a lower surface temperature was presumably due to the presence of a thin layer near the surface of only some few meters in depth, so that the thermometer was not appreciably cooled on passing through it.

Again, the higher temperatures 13° and 15° found by Marsilli in June in depths of respectively 100 and 120 brasses, and which were considered by him as unreliable, are also of doubtful value, since they must be considered in much greater degree due to a layer of water near the surface than to the depths mentioned. The temperature at the surface was then 15°, thus much higher than that recorded by the

thermometer in the deeper layers. The thermometer would thus be warmed up to about 15° during the passage through the warm surface-layer, and that the temperature was not the same in both cases, can scarcely be ascribed to a difference in temperature at the two places, but simply to a difference in the rate of hauling up. The absolute value of the temperatures measured by MARSILLI cannot be controlled and the fact that SAUSSURE later found exactly the same was just a chance, which is no proof of their correctness or that the temperature was the same at the two periods. [1]

The first absolute determination of the temperature below the surface in the Mediterranean was made by SAUSSURE in 1780. For this SAUSSURE used a method [1796, vol. III pp. 153, 196] which was different from those used earlier for measuring the temperature in deep water. He constructed a so-called slow-action thermometer, a principle still widely in use. A Réaumur's spirit-thermometer with a large reservoir was surrounded by a layer ca. 3 inches thick of a mixture of wax, resin and oil, and placed in a basket made of iron-wire. Before the observations were made SAUSSURE studied the insulating power of the apparatus and found that the thermometer only rose 0.1° R. on remaining under constant movement for 10 minutes in water, in which the temperature was about 12° R. higher than that of the apparatus.

SAUSSURE made two observations with this instrument, the one in the neighbourhood of Genoa, the other at Nice, in depths of respectively 288 and 585 meters (886 and 1800 pieds); in both cases the temperature observed was 13.2° C. (10.6° R.), which is surprisingly near the correct value. As a matter of fact also, SAUSSURE reduced his sources of error to the least possible. The apparatus was kept at the desired depth for 12 hours so that it could not but assume the temperature of the surroundings; as the height of the thermometer was not registered when in the deep water the pressure need not be taken account of — apart from the adiabatic expansion of the whole apparatus during the hauling up, a dimension naturally which cannot be reckoned, but which can hardly amount to 0.1° C.

The time taken to haul up the apparatus from the greatest depth is given as 24 minutes and there is thus the possibility that the thermometer got warmed up before the reading; this source of error cannot be determined from the experiment mentioned, as the study of insulated instruments used in later years has led to results, [2] which show that the rise of temperature in the central part of such an instrument proceeds slowly and very regularly in the beginning but after a certain time increases greatly and irregularly, so that it is impossible, in the case mentioned, to extrapolate for rise of temperature during 10 minutes in the above-mentioned experiment of SAUSSURE.

The difference between the temperature of the instrument and that of the water-layer through which it passed on hauling up has not been nearly so great, however, as in the trial experiment, as the latter difference when the experiment was made in October (surface-temperature ca. 20.5° C.) has only amounted to ca. 7° C. and that only for a water-layer of less than 100 meters in thickness nearest the surface, whereas the temperature from 100 to 585 meters did not differ appreciably from the temperature of the thermometer. There is hardly any need, therefore, to correct SAUSSURE's observations for the thermometer during hauling in, as PRESTWICH [1875, p. 592] considers in his most praiseworthy work on the older determinations of the temperature in deep water; and the observations made in quite recent years in the neighbourhood of Monaco have also shown, that high temperatures may well occur in the depths mentioned, similar to those found by SAUSSURE.

During the following period a number of observations of temperature were made in the deep water of

[1] The thermometer used by SAUSSURE was divided according to the Réaumur scale whereas the observations of MARSILLI were made many years before RÉAUMUR (in 1730) described his thermometer and a few years before FAHRENHEIT (probably in 1709) constructed his first thermometer with two fixed points and a definite division of the interval between these. MARSILLI's scale division must therefore be considered as having been quite arbitrary but has nevertheless probably agreed with that of the Florentine Academy, in which the extreme "fixed" points were the lowest winter and highest summer temperatures of Florence.

[2] See e. g. NIELSEN [1904, p. 11] and EKMAN [1905, p. 19].

the oceans, especially by the different circumnavigation expeditions of earlier times, but nearly half a century past before the next observations were made in the deeper layers of the Mediterranean. The French expedition of "l'Astrolabe" under Captain DUMONT D' URVILLE in the years 1826—1829 made 10 obervations of temperature in the Mediterranean on the out and return voyage, most of them near the Straits of Gibraltar. The observations of DUMONT D' URVILLE [1833, p. 51], which were taken in greater depths than 100 meters, are shown in the following table.

1826	IV 27	40° N., 4° 50' E.	488 m.	12.5° C.
—	V 5	Straits of Gibraltar	325 -	12.3° -
—	V 8	5 miles E. of Ceuta	406 -	14.1° -
1829	III 23	41° N., 2° 20' E.	488 -	12.6° -
—	III 22	41° N., 5° 20' E.	977 -	12.6° -

DUMONT D' URVILLE found the agreement with SAUSSURE's observations satisfactory and concluded therefrom, that the deeper water-layers below 300 meters in the Mediterranean have a constant temperature of about 13° C.

The observation 14.1° in the neighbourhood of Ceuta is undoubtedly too high by 1°, whilst the remainder seem almost a little too low, which would indicate that the thermometers used have been protected against the pressure in deep water, and DUMONT D' URVILLE also mentions that two Bunten's "Thermometrographs" were used for registering the temperature. This apparatus consisted of a solid metal cylinder which protected the Six extreme-thermometer inside (maximum and minimum thermometer) so that its readings were independent of the pressure, which varies with the depth. PRESTWICH, on the basis of the temperature observations made in the Atlantic and Indian Oceans, considers that DUMONT D' URVILLE's thermometers were not sufficiently protected against pressure and that this has given too high values for the temperature in deep water. The observations made in the Mediterranean show, on the contrary, that the protection against pressure has been satisfactory and the number of observations at great depths in the ocean are probably too few to be able to decide with certainty, whether the values are too high as the result of the influence of pressure. DUMONT D' URVILLE's erroneous conclusion from his observations, that the temperature in the oceans at depths greater than 1000 meters (600 brasses) was constant and about 4° C., was probably based just as much on the assumption, that seawater like freshwater has its maximum density at 4° C.[1]

In 1831—32 the French Captain BÉRARD [AIMÉ 1845, p. 29] made some observations on the temperature between the French coast and Algiers. Two observations at 1000 meters gave 12.4° and 12.6°, two taken in the depths 1200 and 1233 meters respectively 12.9° and 12.6°, whilst one observation in 2000 meters gave 12.7° C. These observations show good agreement with DUMONT D' URVILLE's earlier observations and are of special interest as they give records down to 2000 meters.

During the French South Pole Expedition in 1837—1840 with "l'Astrolabe" and "la Zélée" under DUMONT D' URVILLE [1841, pp. 3, 4], a few observations of temperature were again made in the Mediterranean on the voyage out, down to ca. 1000 meters, where 12.8° C. was observed. In these observations DUMONT D'URVILLE found a confirmation of his earlier and of the conclusion drawn from them, that the uppermost

[1] That this view was incorrect, had already been shown by MARCET [1819], who found that the density of seawater continues to increase down to freezing point. In agreement with this DESPRETZ [1839] found that the temperature at which seawater has its greatest density diminishes with increasing salinity and that for oceanic water it lies at —3.7° C.

In spite of DESPRETZ' experiment and DU PETIT-THOUARS' observations on the voyage of the frigate "Venus" in 1836—39 [ARAGO 1857, p. 234], which discovered below 3° C. for the temperature in the depths of the oceans, the theory that 4° C. was the lowest temperature at the bottom of the oceans, was long persisted in and found an authoritative supporter in Sir JAMES ROSS, after he himself with unprotected thermometers had always found a temperature of 4—5° C. in great depths, the increase in pressure naturally counterbalancing the existing decrease in temperature.

layer of water, the variable temperature of which he considered dependent on the atmosphere, had no great depth and that the Mediterranean below this had a uniform temperature between 12° and 13° C.

On the basis of DUMONT D' URVILLE and BÉRARD'S observations in the Mediterranean and in the Straits of Gibraltar, ARAGO [1838, 1857] concludes that the cold bottom-water occurring everywhere in the oceans at great depths is not able to force its way into the Mediterranean, and that the temperature in deep water cannot sink lower than the average temperature at the place. Regarding the high temperature observed by DUMONT D'URVILLE in the Bay of Cadiz, ARAGO remarks [1838, p. 213.]: "Ce fait curieux semble se prêter a deux explications différentes. On peut supposer que le courant polaire se trouve complétement refoulé par un courant sous-marin dirigé de la Mediterranée vers l'Océan, et dont l' existence est appuyée sur divers événements de mer. On peut supposer aussi que la saillie si forte de la côte méridionale du Portugal, ne permet pas au flux d'eau froide venant du nord, de s'infléchir, presque à angle droit, pour aller atteindre les régions voisines de l'embouchure du Guadalquivir."

D' URVILLE and BÉRARD'S observations, as well as all the observations of that time made in this manner, give the temperature in deep water on the supposition, that the temperature decreases always with increasing depth (or increases always with the depth); in reality the records thus show only the lowest value of the temperature between the surface and the depths mentioned — supposing naturally that the paying out and hauling in of the thermometer have not proceeded too quickly to allow the thermometer time to accomodate itself to the water-layer in which the temperature is at a minimum. There is consequently the possibility, that the records of both observers must rather be considered as an expression for the temperature in an intermediate layer of water with a minimum temperature as a result of the cooling process in the foregoing winter, a layer of water which will be discussed later.

In the years 1841—45 AIMÉ [1845, p. 5] studied the temperature conditions in the neighbourhood of Algiers and, for the surface-water, on the route Toulon — Algiers. AIMÉ began from an entirely new standpoint; his attention was directed to the variation in the temperature, both the daily and yearly, and he saw clearly that the methods of recording the temperature previously in use (maximum and minimum thermometer on Six's principle with protection as proposed by BUNTEN) did not give information regarding the minima possibly occurring in the upper layers, since the occurrence of these minima would give incorrect readings for the temperature in the deeper layers and conceal any maxima which might occur in the latter.[1] It is not quite clear from his work whether AIMÉ has specially noticed one or perhaps several successive temperature minima, due to the cooling during the winter, but it is also probable that the extensive homothermal water-layer in deep water seemed to him incomprehensible, perhaps from some such considerations as the following. If such a homothermal layer of water really exists, heat must be carried from the bottom to the lowest layers, but this transference of heat will lead to a disturbance of the equilibrium and result in an ascending current and a descent of other bodies of water, which again receive heat from the earth; in short, a vertical movement is started beginning from the bottom of the sea and its cause continues to exist in spite of the vertical currents which have arisen and which tend to eliminate it.

Recognizing correctly that such a vertical movement should be noticeable by a rise of temperature down towards the bottom, AIMÉ modified his thermometers and used a combination of a minimum and reversible thermometer (Thermomètre à retournement à minima) with a maximum and reversible thermo-

[1] AIMÉ writes [1845, p. 7]: "Avec les instruments employés jusqu'à présent pour mesurer les températures de la mer, on a trouvé qu'elles allaient constamment en croissant ou en décroissant, à partir de la surface jusqu'à une certaine profondeur. Il ne devait pas, en effet, en être autrement; car, si l'on suppose que la température de la mer diminue depuis sa surface jusqu'à une certaine profondeur, que plus bas elle augmente, sans toutefois atteindre et dépasser celle de la surface, un thermométrographe, descendu dans la mer, n'indiquera que la température de sa surface et celles des couches les plus froides . . . . C'est pour savoir s'il existe plusieurs maxima de températures, à diverses profondeurs, que j'ai imaginé le thermomètre à retournement".

meter (Thermomètre à retournement à maxima), an apparatus described on p. 7 *et seq.* of the work cited, and placed it in a reversible apparatus, the description of which is given in Ann. d. Chim. et d. Phys. 1843, p. 497. Thus, so far as I know, it is to AIMÉ that the credit is due of having given the stimulus to the appearance and use of reversible thermometers in the study of the temperature conditions of the sea, and he also replaced BUNTEN's impracticable metal cylinder round the thermometer with a glass tube. AIMÉ's "Thermomètre à retournement à minima" was however somewhat complicated and required great care and foresight in using it, just as also the apparatus had to be adjusted each time an observation was made, so that it has probably not been used by others. The results obtained by AIMÉ are naturally far in advance in all regards of what was done during this period, even though he did not attain what he sought after, namely, to prove a rise in the temperature towards the bottom. He mentions an experiment [1845, p. 27], according to which the temperature at a depth of 900 m. was 2° higher than the lowest temperature in the water above; it seems as if the reversible mechanism did not work satisfactorily in such great depths and AIMÉ apparently did not place much weight on this result, as he writes: "Malgré le peu de succes de ces tentatives, ja persiste à croire que la température doit s'élever d'une manière sensible près des couches terrestres du fond de la mer, et, dans tous les cas, on ne pourra affirmer le contraire qu'en employant le moyen de vérification que j'ai indiqué, ou un autre analogue".

In the experiments to determine the daily variation of temperature in the surface-water, AIMÉ's thermometer seems to have worked satisfactorily, as he was successful in demonstrating an intermediate temperature minimum due to the cooling at night; for a large number of experiments carried out at the same place in quiet weather, with disturbing influences as far as possible eliminated, AIMÉ gives the maximum depth for the daily variation of temperature as 18 m. The annual variation in temperature was also investigated by AIMÉ and as result of his observations he gives the following table, showing the annual mean temperature of the sea at different depths.

Depths Meters	Temperature Centigrade	Maximum difference between the monthly mean values.
0	18.2°	10.2°
25	16.3°	6.3°
50	14.4°	2.8°
100	13.7°	2.0°
200	13.0°	1.0°
350	12.6°	0.0°

It appears from the table that the annual variation in temperature is 0 in 350 m., and AIMÉ states that the depth at which any appreciable change in temperature in the course of the year ceases, lies between 350 and 400 m.

AIMÉ's results do not show whether lower temperatures than the 12.6° of the lowest depth noted were observed between the surface and 350 m. or, in other words, whether he has observed any intermediate, annual temperature minimum due to the cooling of the uppermost layer in the previous winter (or an intermediate maximum for observations taken in the coldest period of the year). As this is not expressly stated, it has scarcely been the case and as a matter of fact, though this minimum can be detected, as we shall see later, almost everywhere in the western Mediterranean, it is so little marked that it can only be determined by very exact measurements, and in AIMÉ's case it has probably been of the same dimensions as the errors of observations.

From his observations on the surface temperature at Algiers and the observations made simultaneously at Toulon, AIMÉ gives the following table for the monthly mean temperature of the surface-water.

	Dec.	Jan.	Feb.	March	April
Algiers	15.6°	14.3°	13.2°	13.9°	14.9°
Toulon	13.8°	12.1°	11.9°	11.3°	13.4°
Mean	14.7°	13.2°	12.5°	12.6°	14.2°

The mean temperature for the winter (Jan., Febr., March) is from these results given by AIMÉ as 11.7° for Toulon and 13.8° for Algiers. AIMÉ's conclusion from these results, that 12.7° is the mean temperature for the surface of the Mediterranean in winter, is naturally not quite correct nor the further conclusion: "La température minimum des couches profondes de la Mediterranée est égale à la moyenne des températures de l'hiver à la surface".

This somewhat misleading conclusion is so much the more remarkable as AIMÉ immediately afterwards makes the following valuable remark: Dans la partie méridionale, la température décroît généralement toute l'année, depuis la surface jusqu'a 300 ou 400 mètres. Dans la partie septentrionale, au contraire, la température augmente en hiver jusqu'a cette profondeur; il semble donc que la froide température du fond de la Méditerranée n'est pas déterminée par l'entrée des eaux de l'Océan, mais seulement par la précipitation des couches supérieures pendant l'hiver".

AIMÉ's merit however lies not only in his temperature observations. He also indicated a method of measuring the currents in deep water and even undertook an investigation into the quantity of air absorbed by seawater. In AIMÉ's time the view was widespread, that the amount of air absorbed increased with the depth, i. e. in proportion to the pressure, and consequently assumed a high value at great depths. AIMÉ showed [1843], that the absorbed quantity of air in deep water was of the same magnitude as in the neighbourhood of the surface, a result confirmed later. Nevertheless, the same hypothesis has again and again been put forward — from imaginary experiments based on erroneous presuppositions — whilst misunderstanding of AIMÉ's results has also led to the opposite view, that the absorbed quantity of air in the deeper layers of the Mediterranean was inappreciable.

All the temperature observations mentioned so far were taken in the western basin of the Mediterranean. In the same year (1845) that AIMÉ concluded his epoch-making investigations, Captain SPRATT [1] began some temperature measurements in the Grecian Archipelago and continued them with a break of some years till 1861. All Captain SPRATT's observations were made in the eastern part of the Mediterranean and were carried out in two different ways, which considering the period at which they were made leave a good deal to be desired in the direction of accuracy. The one was the method used earlier by Sir JOHN ROSS and consisted in taking up a quantity of mud from the bottom of the sea, in which after coming up the temperature was measured by an ordinary thermometer. It is obvious that, if no special precautions are taken, the mud will be exposed to changes of temperature on passing through warmer or colder layers of water. A further important objection here is, the observed values are not directly comparable, as the error in determination cannot be considered the same in each experiment; this depends on the quantity of mud taken up, which is naturally not the same in each case and at any rate could never be so well defined as e. g. the quantity of water enclosed in a water-bottle [2]. That this method is quite inapplicable in many cases appears with sufficient distinctness from the observations made by JOHN ROSS in the Davis Straits and Baffins Bay; instead of measuring the bottom temperature ROSS measured rather the temperature in the polar water near the surface. But as these results were in good agreement with the views of that time regarding the distribution of temperature in the sea and

[1] SPRATT's first observations were published in the Philosophical Magazine 1848. As to the later see SPRATT [1862] and [1865, vol. II p. 341], and PRESTWICH [1875] also gives some previously unpublished observations.

[2] Further, differences in the nature of the mud will lead to differences in its conductivity of heat; this I have been able to determine by some experiments on the distribution of the temperature in the mud in the Limfjord, but I shall not discuss these here in detail.

were further confirmed by the use of Six's thermometer — a very natural result according to what has been explained above p. 82 — the application of the method was never called in question.

SPRATT's results for the temperature in the deep water of the Grecian Archipelago, measured in the mud brought up, are curiously enough very reliable. The greatest depth to which SPRATT reached in his measurements, using this method, was 384 m. and the observed temperature was 55.5° F. or 13.1° C.; he found similar records for all depths under ca. 150 m. and concluded from this, that the temperature in deep water in the eastern part of the Mediterranean was constant, just as in the western basin. Later, Capt. SPRATT began to use Six's thermometer and with this made observations in the eastern Mediterranean down to a depth of 2267 m. These might be said to confirm the earlier in so far, that they also gave constant values for the temperature in deep water, but SPRATT now found the constant values ca. 59° F. or 15.0° C.

As the thermometer was not protected against the outer pressure, it is not remarkable that the records for great depths were a good deal too high, but the value 15° C. seems undeniably a little too high to be explicable in this way. That the pressure at the greatest depth (ca. 230 atmospheres) could effect an apparent rise of temperature of a little over 1° C., certainly seems not improbable but the matter is not so simple.

Let us assume that the temperature decreases from the surface downwards, taking the value 14.0° for 200 meters depth and retaining this right to the bottom; assume, further, that the pressure coefficient of the thermometer is 0.01° C. per atmosphere and that the thermometer is let down at such a rate that in passing through a layer of 200 m. in depth it assumes the temperature of this, then the index for the maximum will approximately register the temperature of the surface, let us say 20° C.; as the thermometer goes down it meets with colder layers of water and after passing the layer from 200 to 400 m., it will have assumed the temperature 14.0° according to the above view, but owing to the compression under the ca. 40 atmospheres it will show $14.0 + 40 \times 0.01 = 14.4°$ C. If the thermometer is sunk still deeper through the homothermal water-layer, its temperature remains unchanged at 14.0°, but its momentary record rises in proportion to the depth, and in 2000 m. it will show $14.0 + 200 \times 0.01 = 16.0°$ C. The maximum index however is not influenced by this (as we assumed that it had become set at 20° in the surface-layer), nor the minimum index; after hauling in the minimum temperature 14.4° registered at 400 m. is read, though the actual temperature there was 14.0°. We see from this example, that in a water-layer with constant temperature, an unprotected extreme thermometer will register in the same way as in a layer with an intermediate minimum, that is, will only register this temperature however deep it may go down and not the succeeding maximum, unless the latter is an absolute maximum (higher than the temperature at the surface).

We see from this that, though SPRATT's thermometer was not independent of the pressure, we could not expect that its records would rise with the depths but rather that below a certain depth it would remain constant; if, however, the pressure coefficient of the thermometer was somewhat greater than assumed in the above sample, or the thermometer has been let down somewhat more rapidly, so that it has only assumed the temperature of the surroundings at a greater depth than assumed above [1], the improbable high value for the temperature in deep water might be explained. On the other hand, the values SPRATT found for the bottom temperature in the Aegean Sea, on measuring the temperature of the mud, are on the whole lower than the later values. This applies especially to the two observations in the Sea of Marmora, which were 12.2° and 12.5° for depths of about 100 m.; this

[1] In this case it can readily be seen from what has been explained above, that we should expect a minimum in the temperature above the homothermal layer, e. g. about 200 m., as the temperature is almost the same but the pressure less; this is not apparent however from SPRATT's observations.

seems somewhat inexplicable, as the sources of error in the method, at the time when the observations were made, tend to give too high values.

On the Austrian sailing expedition round the world with the frigate "Novara" under the command of Admiral Wüllerstorf-Urbair [1862, p. 139 *et seq.*], some observations of temperature were made in 1857 from the Ionian Isles to Gibraltar; these observations however, which were made at depths of down to ca. 230 m. (125 fathoms), give extremely discordant results. Thus, the observations made in the above depth in the western part of the Mediterranean, gave values which vary from 13.6° to 15.2°, even 16.1° C. was observed at a depth of ca. 200 m. As these values are throughout too high, it seems reasonable to assume that the insulation of the apparatus used has been insufficient. The maximum and minimum thermometers were certainly sometime used, but as a rule the observations were made after the oldest of the previously known methods for measuring the temperature of the sea, namely, that of Hales [1752, p. 214]. On the "Novara" a cylinder of wood was used with valves above and below through which the water flowed freely on the descent; on hauling up the valves closed and the temperature was measured from the water in the cylinder. As Wüllerstorf's observations were made in the beginning of summer, however, at a time when the warm surface-layer is not very thick, we might expect that no appreciable heating of the water enclosed in the wooden cylinder would occur, and the high values are possibly due to another source of error, namely, leakage at the valves, so that the warmer surface-water through which the cylinder passed on hauling up was able partly to stream through it.

Regarding the distribution of the salinity in the Mediterranean extremely confused and erroneous views prevailed up to 1870. One of the principal reasons for this lay probably in some determinations of Wollaston [1829.] The English Admiral Smyth [1854, p. 130] had taken 3 water-samples in the western part of the Meditterranean from depths of ca. 730, 820 and 1225 m.[1] and the salinity of these was determined by Wollaston. In the two first-mentioned the latter found a value which was only a little higher than that of the surface-water, namely 3.99 and 4.05 p. c. respectively, whilst in the last he found a salinity of 17.3 p. c. The explanation of this is, probably, that the samples were kept for some years before analysis, and the high value has been due to the evaporation of the water, but it certainly seems remarkable, that more than three-fourths of the water could have evaporated without attention being called to the fact.

As it was already known by this time, that the supply of fresh water from rain and rivers does not compensate for the evaporation from the surface of the Mediterranean, and as it was also known that water flows in through the Straits of Gibraltar from the Atlantic, the conclusion was drawn, that the Atlantic water served to replace the excess of evaporation over rainfall. Unless we assume that an outflow also takes place through the Straits of Gibraltar, in which Arago seems to have been inclined to believe on the basis of Dumont d'Urville's observations, the result would be that a certain amount of salt is added yearly to the Mediterranean, namely, the amount contained in the water coming from the Atlantic. By evaporation the seawater becomes concentrated and as the density increases with the concentration, it was assumed that this more saline water sank to the bottom. Thus, in the course of time a bottom-layer must be formed of very high salinity, and some of the supporters of this theory even went so far as to maintain, that a precipitation of the salt must eventually take place when the solution had become saturated, and endeavoured to explain the formation of the natural stone-salt in an analogous manner.

It seems quite incomprehensible, that such a view could win adherents; as the cause of the high salinity in the bottom-layer was supposed to be evaporation from the surface, it follows that at some

[1] A sounding made at the last place by Carpenter in 1870 showed that the depth was only 1070 m.

place or other in the Mediterranean there must be an area in which the salinity at the surface was at least just as high as the supposed high value in the bottom-layer, but all the determinations made of the surface salinity gave results which were not appreciably higher than those obtained in the oceans[1]. These comparatively few and scattered determinations are not comparable with one another, as they were made according to very different methods. SPRATT [1865], for example, found the salinity of the surface-water by determining how much salt dissolved in a certain volume of freshwater was required to give a solution with the same density as the seawater.

The first extensive investigation on the distribution of the salinity in the different parts of the Mediterranean was due to the Danish chemist Prof. FORCHHAMMER'S fundamental work on the salinity of seawater in the different seas. FORCHHAMMER'S analyses of Mediterranean samples [1865, p. 203], which were not restricted to the surface-water only but also embraced samples taken at depths down to 200 m., showed that the proportion between the different components of the dissolved salts was very nearly the same for the Mediterranean water [2] as for oceanic water, and that the total quantity of salt amounted at most to two per mille more than the highest value for oceanic water. As average value for the samples investigated of Mediterranean water FORCHHAMMER found the salinity 37.936‰: the lowest value for the surface salinity 36.301‰ occurred in the neighbourhood of Gibraltar, the highest 39.257‰ was found between Crete and the Libyan coast. Between the Balearic Isles and Spain the value 38.058‰ was found, in the Tyrrhenian Sea between Sardinia and Naples 38.654, in the neighbourhood of Malta 38.541, and in the neighbourhood of Greece a somewhat lower value 38.013‰, which FORCHHAMMER considered due to the outflow of freshwater from the Black Sea.

II. The period after 1870.

After the English "Lightning" Expedition of 1868 in the Northern Atlantic (Faeroes-Scotland) had demonstrated that the distribution of temperature in deep water was quite different from what had previously been the general belief, and in connection therewith had shown that important faunistic differences occurred in parts of the sea adjacent to one another, several larger expeditions were fitted out in England in the following years with the object of making a rational investigation of the deep water. Of these expeditions the "Porcupine" under CARPENTER investigated the western part of the Mediterranean in the year 1870 [CARPENTER and JEFFREYS 1871], and these investigations were supplemented in the following year by the "Shearwater" Expedition, which extended its investigations also to the eastern basin of the Mediterranean [CARPENTER 1872]. These expeditions mark the beginning of a new era in oceanography, in that physical, chemical and biological investigations were all carried out at the same time, whereas previously attention had as a rule been restricted to one single field, with the result that the data obtained were very often in opposition to one another.

The thermometers used on the "Porcupine" and "Shearwater" expeditions were constructed by

[1] The supposition of such a very saline or even saturated water-layer at the bottom of the Mediterranean was also a weighty support for the long prevailing view, that all animal life in the Mediterranean ceased at depths greater than 100 fathoms, but the final proof of the untenability of this view appeared in 1861, when a cable-steamer, on repairing a cable between Cagliari and Bona, obtained several living animals attached to the cable, some of them from depths greater than 2000 m. The fact that living organisms existed at such great depths was naturally the death-blow to the hypothesis, that a strongly concentrated solution of salt occurred at these depths.

[2] That the composition of the dissolved salts was the same, even though the total quantity of salt was different, had earlier been proved by CALAMAI [1848] from analyses of surface-water at Leghorn and Venice.

Casella on Six's principle and on the proposal of Dr. Miller [1869] the thermometer was surrounded by a solid glass-casing; the interspace between this and the thermometer was almost filled with alcohol and the remaining space only contained alcohol vapour, as before fusing the air had been driven out by boiling the alcohol. In this way the influence of pressure on the thermometer is avoided, an increase in the outer pressure only producing a diminution of the space occupied by the alcohol vapour. A similar method however had previously been proposed by Admiral Fitzroy, only with mercury instead of alcohol, but it seems as if the mechanical work had been at fault. Casella's thermometer seems to have been excellent and in the immediately succeeding years the Miller-Casella thermometer was used exclusively in measuring the temperature of deep water.

Before the start of the expedition the thermometers were tested under a pressure of about 500 atmospheres and no change could be noted in the reading with certainty as a result of the compression of the reservoir (Davis [1870, p. 347], Carpenter [1871, p. 397]).

In August and September 1870 Dr. Carpenter carried out a series of soundings with determination of the bottom-temperature in the southern part of the western basin of the Mediterranean, from the Straits of Gibraltar to a little east of Malta, as also a few in the southern part of the Tyrrhenian Sea. Like Aimé earlier, Carpenter made a series of determinations at three stations in order to be certain that the observed values really gave the bottom-temperature and not the minimum temperature temperature in an intermediate layer lying above. In these serial determinations the temperature was measured at the surface and also at the depths 10, 20, 30, 40, 50, and 100 fathoms (182.9 m.) and further the bottom-temperature; from these observations and from comparison of the bottom-temperatures measured at different depths, Carpenter came to the result, that the temperature decreases from the surface down to a depth of ca. 100 fathoms, below which it remains constant right to the greatest depths. Carpenter remarks on this [1871, p. 195]: "In fact, whatever the temperature was at 100 fathoms, that was the temperature of the whole mass of water beneath, down to the greatest depth explored".

On the other hand, some variation in the temperature was observed from place to place, but this variation was not regular, either in regard to depth or position; from the Straits of Gibraltar to Sardinia the observed bottom-temperatures (at depths greater than 100 fathoms) varied from 54° to 55.5° F. (12.2° to 13.1° C.), and the mean value of all the observations was 54.9° F. (12.7° C.).

East of Pantellaria (South of Sicily) the observed bottom-temperatures were somewhat higher, varying from 55° to 56.5° F. with the mean value 55.8° F. (13.2° C.). As Carpenter imagined that this higher value might possibly come from volcanic agency, a couple of soundings were made in the southern part of the Tyrrhenian Sea, between Etna and Stromboli, which gave respectively 55.3° and 55.7° F, (mean 13.1° C.). On the next year's cruise with the "Shearwater", however, Carpenter discovered the correct explanation of this apparent discrepancy, as it was found that higher bottom-temperatures occurred everywhere in the eastern basin, wherever observations were made, than in the western; for example, at two stations where serial determinations were made (35° 54′ N., 16° 23′ E., 1650 fathoms and 32° 17.5′ N., 26° 44′ E., 1970 fathoms), 56.0° and 56.7° F. or 13.3° and 13.7° C. were found; it appeared further from these serial observations, that the water-layer nearest the surface, in which the temperature varies, increases in thickness towards the east and "that the temperature of the stratum between 100 and 200 fathoms still exhibits in the Eastern basin some evidence of being influenced by direct insolation-the bottom-temperature which is met with in the western basin at all depths below 100 fathoms being here not encountered until 200 fathoms have been passed" (Carpenter [1872, p. 580]. The surface-temperature in the eastern basin was also considerably higher than in the western and Carpenter saw in this higher surface-temperature and the consequently greater evaporation the reason for the warmth of the water from the surface down to a depth of 200 fathoms; this will be discussed in more detail below under the determinations of the salinity.

CARPENTER seeks to explain the constant value of the temperature in the extensive bottom-layer of the Mediterranean as being equal to the mean temperature of the earth [1871, p. 196] and in support of this he mentions, that a Lieut. MILLER in summer measured a temperature of 54° F. (12.2° C.) in a hole on Pantellaria and that the water at the bottom of the deepest tanks, protected against direct sunshine in Malta, also had the same temperature. This seems unquestionably a backward step from AIMÉ's view mentioned above, that the temperature in deep water is the same as that of the surface water in the coldest period of the year, yet CARPENTER also speaks of a descent of surface-water in the cold period of the year, though he supposes that this descent does not reach to the greatest depths but is restricted mainly to the surface-layer which is warmed up in summer. The reason for this view seems to have been that CARPENTER underestimated the cooling of the surface-water in the course of the winter, as he remarks [1871, p. 197]: "In no instance, however, as far as we can learn, has the surface-temperature of the Mediterranean ever been seen so low as 56° F. (13.3° C.), even in midwinter." Later, however [1872, p, 581], CARPENTER states that the lowest mean value of the surface-temperature in winter determines the value of the bottom-temperature. For the portions of the Mediterranean (southern part), in which CARPENTER's investigations were carried out, it is undoubtedly correct that the temperature at the surface does not become so low, that there can be any talk of a downward flow of surface-water to the greatest depths, but this process certainly goes on further to the North.

The English investigations of the "Porcupine" and "Shearwater" in 1870—71 were not only the first systematic endeavour to determine the vertical distribution of temperature in the different parts of the Mediterranean, they may also be said, to an even higher degree, to have been the first to undertake the investigation of the distribution of salinity. The determinations were made according to two essentially different methods, on the one hand determination of the density by means of the areometer, on the other, determination of the quantity of chlorine in a certain quantity of seawater, and the results from these two methods agreed well together. The data are given in slightly different units from those generally used in later years; the quantity of chlorine, for example, in gms. per 1000 cm^3 seawater, whilst the quantities of chlorine registered in the tables of the "Thor's" observations give the amount of chlorine found in 1000 gm. seawater. A reduction in the latter case is quite a simple matter, but this cannot be done for the density without some uncertainty, as the thermal expansion of the kind of glass used in the areometer has some influence on the reducing factor; in this connection, however, such a reduction is not of such great importance, as it is chiefly the relative values which are of interest.

On the basis of his determinations of the amount of chlorine and density of the Mediterranean water CARPENTER points out an ingoing current through the Straits of Gibraltar of the surface-water from the Atlantic; the further we go from the Straits of Gibraltar towards the east, the greater becomes the salinity at the surface, which CARPENTER explains as due to evaporation alone, an explanation not entirely correct, as the mixing with the true Mediterranean water is certainly not without importance. Below this ingoing water with lower and variable salinity CARPENTER found an extensive layer of water in which the salinity varied but little, the layer namely which has a constant temperature. In the eastern part of the Mediterranean, off the Libyan coast, the concentration produced by evaporation was so far advanced, that the density of the surface-water was almost the same as that of the bottom-water. CARPENTER found here 1.0293 for the surface and 1.0294 at 1650 fathoms, whilst a second station in this region gave 1.0294 for the surface-water, 1.0302 at 365 fathoms [1872, p. 582]. It may be remarked here that the density at a depth of 365 fathoms (667 m.) is somewhat higher than the density both at the surface and in greater depths, a phenomenon also apparent from the observations in the western part of the Mediterranean, as is indicated in the accompanying table showing the amount of chlorine in bottom-water taken at depths between the limits mentioned.

Fathoms	Cl.
200—400	21.53 ‰ (mean of 7 obser.)
400—800	21.38 ‰ (— - 7 —)
1300—1700	21.21 ‰ — - 6 —

The relatively considerable variation in the amount of chlorine with the depth is, however, explained in part perhaps by a portion of the high values at the lesser depths coming from the stations south of Sicily, which must naturally be referred to the eastern part of the Mediterranean, where the amount of chlorine at great depths is higher than in the western basin.

Carpenter gives a very plausible explanation of this vertical distribution of the salinity. Through evaporation from the surface the salinity of even the surface-layer rises, until it obtains the same density as the lower-lying layers; further evaporation now causes a sinking down of salter (and as a rule warmer) surface-water, which is mixed with the deeper water and increases the salinity of the latter, and if this descent of more concentrated surface-water is imagined as continued right to the bottom it is evident, that the increase in salinity which the whole column of water has received at each point, is inversely proportional to the height of the column, and that, consequently, we ought to find higher values for the salinity where the depth is only between 200 and 400 fathoms than where it is down to 1700 fathoms. Carpenter remarks on this [1871, p. 199]: "Since this proves actually to be the case, the further conclusion appears justifiable — that there is an extremely small amount of movement in the abyssal waters of the Mediterranean basin".

However attractive this explanation of the higher value of the salinity at less than at greater depths may be, yet certain objections can be made to it and the principal of these is, that the highest observed quantity of chlorine 21.88 ‰ at a depth of 207 fathoms occurred in the Alboran Sea in the neighbourhood of Cape Tresforcas, thus, at a place where there always is a surface-layer with low salinity, and this surface-layer is in rapid movement eastwards and is replaced by new Atlantic water long before it becomes so concentrated that there can be any talk of its sinking down; the high value for the quantity of chlorine in the bottom-water must then be due to this bottom-water having flowed in from elsewhere. Further, the lowest observed value 21.08 ‰ at 1743 fathoms south-east of Sicily is so divergent from the above maximum 21.88 ‰, that there must have been some error of observation. As we shall show later, however, the general picture we obtain from the above table is to some extent correct, though the difference between the maximum salinity between 200 and 400 fathoms and the salinity at the greatest depths is not so great as appears from the table.

As already mentioned, Carpenter found that the temperature in the eastern part of the Mediterranean only assumed its constant value at depths greater than 200 fathoms, and that the surface-layer, in which the temperature in summer decreases downwards, was almost twice as thick in the eastern as in the western basin. This greater thickness is explained by Carpenter on the grounds that the evaporation from the eastern basin is more intense than from the western, and that the salinity in the surface-layer is in this way increased so much that, in spite of its higher temperature, this layer sinks downwards and carries heat to the deeper layers. The lowermost layer, to which these vertical currents reach in the course of the summer, should thus be at a depth of ca. 200 fathoms in the eastern basin. We shall see later, that this is an overestimation of the influence of the evaporation, as such an intensive sinking of surface-water will only occur on cooling in winter.

Of greatest interest, however, are Carpenter's investigations in and outside the Straits of Gibraltar. From a series of extensive investigations it appeared, on the one hand, that in Cadiz Bay west of the threshold Cape Spartel—Cape Trafalgar there is a bottom-layer with a temperature considerably higher than that at the same level in the Atlantic, and just as high as in the Mediterranean, which gives a confirmation

of Dumont d' Urville's temperature observations; further, the salinity and density observations showed, that the salinity in the bottom-water was just as great as in the Mediterranean. It was thus incontrovertibly established, that an under-current of salt masses of water must run through the Straits of Gibraltar from the Mediterranean out into the Atlantic. This under-current, the existence of which Arago had already been disposed to believe in, was also determined by direct current-measurements on both cruises (Carpenter [1871, p. 166], Nares [1872, p. 97), though these measurements showed great variations dependent on the tidal movements.

Carpenter's work has in the main formed the basis for our present-day knowledge of the hydrographical conditions in the Mediterranean, and the later investigations have in all essentials merely confirmed Carpenter's view, that at the bottom of the whole Mediterranean there lies an extensive homothermal layer of water, in which the temperature is somewhat higher in the eastern than in the western basin; above this lies a layer in which the temperature varies with the time of year and this annual variation extends to a depth of about 200 meters in the western basin, but to nearly twice this depth in the eastern basin. It certainly seems remarkable, that none of the later expeditions have made the distribution of the temperature in a vertical direction the object of a more careful investigation; possibly Carpenter's authority, possibly also this very simple and intelligible, vertical distribution of temperature, has been the reason why it has not been called in question and why it has been left to the investigations of quite recent years to show, that the conditions are in reality much more complicated.

In 1874—76 the Austrians made some investigations in the Adriatic and in 1880 these investigations were extended to the Ionian Sea [Wolf and Luksch 1881]. On the latter occasion the expedition was provided with a reversible thermometer constructed by Kappeler of Vienna in addition to the ordinary Miller-Casella thermometers. This reversible thermometer was however not protected against pressure and was not used very much, as it proved faulty in several regards. The large number of temperature observations seem on the whole very reliable and have a distinct advantage over the earlier, in that observations were generally taken at every 10 m. from the surface down to 160 m.; as a rule the temperature decreases from the surface down to the greatest depth at which regular observations were made (160 m.), but below 100 m. the fall of temperature with increasing depth is very slight. At the greatest depths in the Adriatic (over 1000 m.) a bottom-temperature of 12.9°—13.0° was observed, and similar temperatures were found in relatively shallow depths in the north-eastern part, whilst these colder regions were separated by a region with a bottom-temperature of 13°—14°; but considering the same level everywhere, the observations show a distinct rise in temperature from the north-east to the south-west.

On the basis of these observations, in conjunction with their chemical investigations, Wolf and Luksch show, that the currents of the Adriatic are determined by an in-going stream on the east side of the Straits of Otranto, whilst on the west side of this there is an outflow from the Adriatic of the water-masses mixed with the river-water.

The annual varation of temperature in the northern part of the Adriatic was also investigated during the years mentioned; it was found that the temperature of the surface-layer could fall below 10° C. in winter and that the vertical distribution of temperature in the shallower waters might be the reverse of that which occurs in the summer, namely, increasing temperature with increasing depth. A similar distribution of temperature, however, was also found in the greatest depths of the Adriatic south-west of Ragusa in the winter of 1878 by Hoffgartner, as is shown by the following series of temperatures [Wolf and Luksch 1887]:

Depth	500	550	650	700	775	850	930	1075	1230 m.
Temp.	11.7°	11.6°	11.7°	12.0°	12.1°	12.0°	12.1°	12.2°	12.3°

Until they have received further confirmation, however, these observations should probably be taken with the greatest reservation, especially as regards the absolute values.

In the summer of 1879 SEMMOLA began some investigations into the distribution of temperature in the upper layers of water in the Bay of Naples [CHISTONI 1882], and these investigations were continued in the winter of 1880 in order to determine the depth reached by the annual variation of temperature. For these SEMMOLA used the reversible thermometer constructed a short time previously by NEGRETTI and ZAMBRA and there can thus be no doubt, that the observed values really represent the temperature at the given depth — an objection, which as mentioned above can very often be made against the results obtained by the maximum and minimum thermometers. SEMMOLA found, that the temperature in summer (June-August) decreased down to a depth of a little over 100 meters and then remained constant down to 180 m., at which depth 14.0° C. was observed both in June and August; in the beginning of February the temperature from the surface down to 180 m. was constant at 13.2°; thus, SEMMOLA's observations do not give the lowest limit for the annual variation of temperature.

KRÜMMEL [1907, p. 462] concludes from these observations, that in the beginning of February the temperature is constant in a vertical direction and that this constant temperature is 0.4° higher in the Tyrrhenian basin than in the Balearic; it may be objected to this, however, that a cooling of the surface-water still takes place for some time after this period, and that the surface-layer investigated by SEMMOLA was still possibly at this period, though homotherm, different as regards temperature from the deeper layers; but even if the observations do not give information on this point, they are nevertheless of great interest, as they show that a very extensive, homothermal surface-layer occurs in winter due to cooling at the surface, but, as we shall see later, it appears from our observations, that this constant temperature is restricted to the surface-layer in the Tyrrhenian Sea and that there is an intermediate maximum below this.

The only contribution which France has made to the hydrographical investigation of the deep water of the Mediterranean since the observations of DUMONT D'URVILLE, comes from the Expedition of "le Travailleur" in 1881 in the western part of the Mediterranean, from the Straits of Gibraltar westward round the Balearic Isles to Corsica and the French coast [MILNE EDWARDS 1882]. On this Expedition the Miller-Casella thermometers were still used and the observations made in deep water are thus open to the objection already mentioned, namely, that the values obtained are possibly more dependent on the temperature in an intermediate, colder layer than on the temperature in the depth mentioned.

The observations under the surface are confined as a rule to the determinations of the bottom-temperature and these are remarkable for their great constancy; of 17 observations made in depths from 250 to 2660 meters, 15 give the value 13.0° and only 2 differ from this with 13.5° and 13.7°. The thickness of the layer, within which the temperature varies in the course of the year, is given by MILNE EDWARDS as 200—250 m. and he remarks [1882, p. 25]: "La température des couches inférieures de la Méditerranée est d'une constance parfaite. . . Il y a donc là une immense nappe d'eau presque immobile". In reality the temperatures at depths below 250 m. are far from being so uniform, as the above values would lead us to suppose, and the constant value so often repeated might almost indicate that there has been an error in the construction of the thermometer.

For the determination of the chlorine content in some water-samples from the Mediterranean BOUQUET DE LA GRYE [1882] uses MOHR's titration method, which he modifies so as to give rapid and relatively certain determinations of the quantity of chlorine; in this form the method has been extensively used in recent years in hydrography, and has been supplemented on the proposal of M. KNUDSEN by the use of a sample with known quantity of chlorine (normal water) for the determination of the absolute values; it has the special advantage of enabling chlorine titrations to be made on board ship. On the basis of his determinations of the density of Mediterranean water BOUQUET DE LA GRYE also made an interesting attempt to calculate the difference in level between the Mediterranean at the south-east coast of France and the Atlantic at Biarritz.

Semmola's studies on the temperature of the upper water-layers in the Bay of Naples were soon followed by more extensive oceanographical investigations from Italy. In the summer of 1881 the Italian government fitted out the steamer "Washington" under the command of Magnaghi for the purpose of making zoological and hydrographical investigations in the Tyrrhenian Sea. These investigations were continued in the following years in the Ionian and Balearic Seas, and the currents in the Straits of Gibraltar and in the Dardanelles were also studied.

On the "Washington" Expeditions the reversible thermometers of Negretti and Zambra were for the first time used on an extensive scale for the determination of the temperature in deep water. The practical value of the apparatus was greatly increased by Magnaghi on these expeditions; instead of the original reversible apparatus of Negretti and Zambra a framework was used in which the thermometer was maintained in a vertical position during the descent by means of an axle provided with a propeller. When the thermometer has assumed the temperature of the surroundings and the hauling-in has begun, the pressure of the water acting on the propeller causes the axle to move in a longitudinal direction and thus set free the pinion which keeps the thermometer in a vertical position; a counterpoise on the framework then causes the thermometer to turn 180° round its horizontal axis and the temperature is registered in the usual manner. This apparatus, which has repeatedly been used on deep-sea expeditions since that time, seems to have worked in an extremely satisfactory way in its original form and the temperature observations made by Magnaghi seem very trustworthy and are much superior to all the temperature measurements made earlier.

These temperature observations have the greatest interest naturally from the fact, that the method used is independent of the more or less disputable presuppositions on the vertical distribution of the temperature; the method really gives the temperature existing at a definite depth. At the same time it is worthy of remark, that a large number of observations were made in the same series, thus at small intervals, so that it is possible to distinguish between actually existing irregularities in the distribution of the temperature and errors of observation, since the former will appear in several, successive observations.

As an example of this we may take the observations of the "Washington" at St. 31, 39° 20′ 28″ N. L., 13° 10′ 38″ E. L., depth 3624 m., on August 27th 1881 [Gigliolo and Issel 1884].

Depth	0	20	30	50	80	100	150	200	300	400	500	600	800	1000	1500	2500	3550
Temp.	26°	25.3°	19.5°	16.8°	14.9°	14.5°	14.3°	14.0°	14.0°	14.2°	14.1°	14.0°	13.5°	13.6°	13.4°	13.3°	13.3°

We see from these observations, that there is a maximum of temperature at a depth of 400—500 m., and there is no reason to doubt its existence, as it is present in the two independent observations at 400 and 500 m.; the same applies to the temperature minimum at 200—300 m., whereas the irregularities in the temperature from 800 to 1500 m. are probably due to errors of observation; in any case it cannot be concluded from the observations that they really existed.

A similar distribution of the temperature occurs at several of the other stations of the "Washington", although the minimum and succeeding maximum may be at different depths at different places. It is thus quite clear from these observations, that Carpenter's view, that the water-layer in which the temperature varies in the course of the year only reaches down to a depth of ca. 200 m. in the western basin of the Mediterranean and that the temperature from there down to the bottom is quite constant, is not altogether correct; at depths greater than 200 m. the temperature variations are certainly very slight, amounting to only a few tenths of a degree, but this slight difference has nevertheless great importance for understanding the circulation of these water-masses.

This remarkable distribution of temperature, with a minimum below the warm surface-layer and a succeeding maximum, seems however to have escaped attention and the reason for this is, probably, that the maximum referred to is but little marked (only 0.2° higher than the minimum), though the fact that no general summary of the results of the Expedition has been published, so far as I am aware, but only

some short, scattered notices, has possibly also contributed to these observations not receiving the attention they merited. Further, the Italian oceanographeres themselves do not seem to have taken any special note of this minimum and maximum of temperature or attempted to give any explanation of this remarkable condition.

On this Expedition interesting experiments were also made on the measurement of the currents at great depths in the Tyrrhenian Sea; at a depth of ca. 3000 m. the ship was anchored by means of the trawl warp, and the result of the current-measurements was, that the surface-current (from 0—10 m.) ran from the S. E. at a rate of 1200—1300 m. per hour, at 100 meters the current ran in an opposite direction, from the N. W., at a rate of 150—200 m. per hour, and at a depth of 500 m. no current could be detected [Chierchia 1882, p. 437, Giglioli & Issel 1884, p. 246].

The density of some of the water-samples taken by the "Washington" Expedition was determined by Reggiani [1890, p. 90] by means of the areometer with total immersion, but the observed values, in spite of the great exactness with which they seem to have been determined, do not give a reliable picture of the vertical distribution of the density or salinity.

The Russians, whose oceanographical investigations in the Black Sea[1] have given such remarkable results, are also represented in the investigation of the true Mediterranean, as the distinguished Admiral Makaroff [1894] took a series of stations from the eastern part of the Mediterranean to the Straits of Gibraltar on the cruise of the "Vitiaz" through the Mediterranean in 1889. At these stations temperature and areometric observations were made as a rule down to depths of 800 m.

Of special interest are the stations 214 and 215 at respectively 32° 31′ N. L,, 31° 01′ E. L. and 36° 29′ N. L., 27° 47′ E. L. At the first of these, investigated on March 17th 1889, the temperature decreased from a little over 16° at the surface to 13.7° at 800 meters, whilst the salinity rose a little from the surface to a depth of 100—200 m., where it reached a maximum and thereafter decreased slightly with increasing depth. At station 215, investigated a few days later (21/3) the temperature was constant from the surface down to at least 200 m. and had the value 16.0°—16.1,° whilst the salinity was quite constant (39.07‰) in the whole of the water-layer in which observations were made, at this station only down to 400 m.

Makaroff concludes from this, that in the eastern part of the Mediterranean in the neighbourhood of the Syrian coast the surface-water must sink down in winter and in support of this he mentions, that the "Wind and Current charts" published by the English Admiralty in 1886 give 13.3° C. for the temperature in February at the Syrian coast. It is evident, that when the surface-water over such a homohaline water-column is cooled down to the same temperature as that obtaining in the deeper layers, any further cooling will lead to an intensive sinking of the surface-water, but at the time when Makaroff's observations were made, the conditions of equilibrium were very stable, so that during the winter in question there could not have been any vertical currents from the surface to the greatest depths. Contrary to what Makaroff assumes, we may believe that it is only exceptionally, that the cooling of the surface-water is sufficiently great to lead to a descent of this water to the greatest depths, and the salinity of the bottom-water has certainly been different from that found by Makaroff in the upper layers. The fact, however, that an extensive, homohaline layer occurs at the surface in winter, is of great importance for understanding the conditions in the upper layers, and in any case it is to Makaroff that we owe a theoretically plausible explanation of the origin and renewal of the bottom-water.

Further to the west, in the neighbourhood of Malta, Makaroff discovered considerable traces of the Atlantic water, which flows in through the Straits of Gibraltar and is appreciable down to a depth of about 200 meters. At this depth the salinity is ca. 38.5‰, a value that he found in the whole of the western basin at depths of 400 m. or more. Makaroff concludes [1894, p. 198] that the water-masses which sink down in the eastern part of the Mediterranean move in the deep water towards the west and on the threshold between Sicily and Africa become mixed with the less saline surface-layer, and that it is the

[1] A brief summary of the results of these investigations will be given below in discussing our results from the Black Sea.

product of this mixing process which determines the value of the salinity in the deep water of the western basin.

Whilst the salinity of 38.5‰ was always found in the western basin at a depth of 400 m. MAKAROFF found that the temperature decreased by 0.6° in the depths mentioned, namely from 13.5° in the neighbourhood of Malta to 12.9° towards the Straits of Gibraltar; St. 219, 37° 34′ N. L., 6° 16′ E. L., investigated on April 30th 1889, is of special interest, as the vertical distribution of the temperature is analogous with that found from our observations. This can be seen from the following results:

Depth	0	25	50	100	150	200	400	800 m.
Temp.	14.8°	14.5°	13.9°	12.9°	12.7°	13.0°	13.5°	13.2°

At two of the other stations there is also an indication of such a temperature minimum in the intermediate layers, but the succeeding intermediate maximum is only represented at the above station. From such an isolated observation it is naturally not possible to draw any general conclusion, nor does MAKAROFF seem inclined to give it any importance; the intermediate maximum as regards the salinity, which we constantly find in our observations, does not appear in MAKAROFF's and as it is but little marked, we may doubt whether areometric measurements on board ship could detect it with certainty.

From investigations made at a series of stations in the Straits of Gibraltar, MAKAROFF further discusses the currents in this and shows, that the inflowing Atlantic water decreases in thickness towards the narrowest part of the Straits, but after passing this it again extends a little deeper down; in the narrowest part of the Straits the thickness of the inflowing Atlantic water is a little over 100 m.

In the year after MAKAROFF's investigations the eastern basin of the Mediterranean was subjected to a thorough and detailled study. This time it was the Austrian "Pola" Expedition, which was engaged in zoological and physico-chemical investigations during the years 1890—93. In 1890—91 these investigations were carried out in the Ionian Sea and extended eastwards to Alexandria and Crete; in 1892 they were carried further to the east as far as the coast of Syria, and in 1893, lastly, the Aegean Sea was investigated. In 1894 as a supplement to these came the investigations in the Sea of Marmora, undertaken by KONRAD NATTERER with the ship "Taurus".

These investigations show, that the temperature at great depths only varies extremely little in the eastern basin; according to LUKSCH and WOLF [1893, p. 122] the temperatures observed at depths of 1000 m. or more lie between 13.5° and 13.7°, as a rule 13.6°, results which are in good agreement with both CARPENTER and MAKAROFF's observations of the temperature, and the above authors conclude from this, that the temperature in the eastern basin of the Mediterranean is constant at great depths just as in the western basin, but that the constant temperature in the former is between ½ and 1 degree higher than in the latter. In the surface-layer, as was to be expected, considerably higher values were found in the southern part of the basin than in the northern, and this applies not only to the surface itself but also to the whole layer down to 100 m., a similar though somewhat less marked decrease in the temperature from south to north also occurring at a depth of 100 m.

It is possible that this variation with the latitude might also be found at greater depths, but it cannot be shown with certainty, as the observations were not carried on regularly at the same level below 100 m. It is not improbable, that a larger number of observations taken at shorter intervals, would have given quite different and interesting information regarding the distribution of temperature from the surface to depths of 500 to 1000 m., similar to what we have found in the whole of the western basin and in part in the Ionian Sea. The idea of such a division into layers with intermediate maxima and minima of temperature, seems to have remained quite dormant after AIMÉ's time, and this is probably the reason why there was no definite plan in the investigation of the intermediate layers. Further, the MILLER-CASELLA thermometers were the ones mostly used, though controlled by the NEGRETTI-ZAMBRA reversible thermo-

meter with which the Expedition was also provided, and as we have already repeatedly remarked, extreme-thermometers will not in general give information regarding the intermediate temperature maxima.

The salinity was determined with the areometer on board ship and these determinations were frequently controlled by measurements with the pycnometer; further, a large number of water-samples from different localities and different depths were subjected to chemical analysis. These determinations show, that the lowest salinity occurs along the coast of Africa, but that the salinity increases towards the east as far as to the mouth of the Nile; from there after a very sudden decrease it again rises somewhat and along the whole coast of Syria and Asia Minor there is a belt of lower salinity, whilst the highest salinity is found to the south and west of Cyprus. Luksch and Wolf conclude from this [1893, p. 126], that there is a cyclonic movement of the currents in the eastern part of the Mediterranean with an east-going current on the south side of the basin and a west-going current along the coast of Asia Minor.

West of Cyprus, where the maximum salinity was found, the salinity decreased from the surface downwards, a condition that occurred almost everywhere, however, except where special conditions prevailed (rivers etc.), and where these special conditions affected the surface-water, then an intermediate maximum of salinity was as a rule found with decreasing values down towards the bottom. Luksch and Wolf, who had already noticed this condition in the Adriatic and in the neighbourhood of Sicily and had concluded for these places, that it came from a dilution of the bottom-water from submarine springs, now explain the phenomenon as due to the evaporation from the surface with greater concentration of the surface-water and consequent sinking down of this more saline water.

This explanation, which is completely satisfactory where the highest salinity occurs in the surface-water, cannot be used however in cases where the maximum of the salinity lies in the intermediate layers; but the authors mentioned remark, that this distribution may frequently arise from a mixing of the surface-water with fresher masses of water, and where such a cause is excluded, they assume that the evaporation at the time when the observations were made, was less than at an earlier period and that the condition found must have been the consequence of an earlier combination of causes. This explanation is however quite unsatisfactory, as such a lower salinity at the surface can only be imagined as arising from intermediate currents or actual sources of dilution, and where these conditions do not exist it will not occur even if the evaporation should wholly cease.

The chemical analyses made by Natterer are of considerable interest, especially the determinations of the absorbed quantity of oxygen and bromine contents. The oxygen determinations show, when we exclude one single sample from the Ionian Sea, that the absorbed quantity of oxygen even at the greatest depths in the eastern part of the Mediterranean does not fall below the two-thirds of the amount, which the sample would contain if it were saturated with oxygen at the temperature observed [Natterer 1893, p. 70]. It follows from this, that there must be an active circulation in a vertical direction in the eastern part of the Mediterranean, as the quantity of oxygen would otherwise rapidly decrease under the reducing processes in deep water, a phenomenon well-known in the deepest parts of the Baltic and in the Black Sea, where the reducing process is even so far advanced, that the deep water contains appreciable quantites of hydrogen sulphide, which excludes all animal life. The old view, that similar conditions occur in the deeper parts of the Mediterranean, the improbability of which had however long been shown, thus finds not the slightest support in Natterer's investigations on the quantity of oxygen in the deeper layers of water.

On the African coast Natterer found a minimum for the bromine occurring in seawater, as the quantity of bromine in the Mediterranean water, which normally has the same value as in oceanic water, namely ca. 0.07‰ or in proportion to the quantity of chlorine 0.33% [Sørensen 1902, p. 93], here falls so low as 0.04‰ or 0.2% of the quantity of chlorine. This low value, which occurs in the neighbourhood of the surface from Solum Bay to the mouth of the Nile, and whose origin is ascribed by Natterer

to bromine absorbing plants (algae), was detected in the deep water of the most eastern basin towards Syria and Cypus. From this NATTERER concludes, [1894, p. 37], that the surface-water flowing eastwards along the coast of Africa, which has attained a high degree of concentration from the evaporation in summer, sinks down on cooling in winter into the deep region of the easternmost basin.

From the investigations of 1893 in the Aegean Sea [LUKSCH and WOLF 1894] it appears, that the temperature in the deep water there is far from being so constant as in the open Mediterranean; in the northern part it is less than 13° C. at depths of ca. 1000 m., whilst towards Crete it is almost the same as to the south of that island. This finds a natural explanation in the fact, that the depths in the Aegean Sea are irregular and several small, deeper regions occur, separated by ridges which shut off the bottom-water from direct communication by means of horizontal currents; in fact we have here on a smaller scale analogies with the Mediterranean itself, as the temperature in the deep water of each of these smaller basins is determined by the meteorological conditions prevailing over the basin itself. The salinity shows very considerable variations, an inflow of salt water-masses from the Mediterranean occurring along the coast of Asia Minor, whilst in the northern part the salinity is considerably reduced (to below 33‰) by the freshwater streaming out from the Black Sea through the Sea of Marmora. This fresher water keeps to the west side of the basin and can be followed by means of the lower salinity in the uppermost layers along the Grecian coast. At greater depths the variations in the salinity are naturally much smaller, though there is an appreciable rise (ca. 1‰) from the northern part towards Crete, where we find almost the same salinity as in the eastern basin of the Mediterranean.

As all these investigations were carried out in summer, they can naturally give no answer to the important question, discussed by MAKAROFF, at what places the surface-conditions in the course of the winter are such, that vertical currents can originate from the surface and thus lead to a renewal of the bottom-water.

The investigations which have been carried out in the western basin of the Mediterranean since those of Admiral MAKAROFF in 1889, are for the most part due to the unique interest taken in oceanographical questions by the PRINCE of MONACO.

Simultaneously with the above-mentioned investigations of the Austrians in the eastern part of the Mediterranean, J. Y. BUCHANAN, the hydrographer of the "Challenger" Expedition, undertook a series of important investigations in the western part of the Mediterranean on the Prince of Monaco's yacht "Princesse Alice" (Aug.-Sept. 1892). The object of these investigations was to determine, how far the relation betveen the alkalinity and density of seawater was the same in the Mediterranean as in the Atlantic, and they were carried out on the voyage from Dartmouth to Genoa. The density was determined by BUCHANAN [1893, p. 1321] with areometers of the same type as those used on the "Challenger" Expedition, but with certain improvements, so that it was always possible to control the determinations by experiments with distilled water. For each water-sample Buchanan made at least 3 independent determinations and concludes from these experiments, that the error in the average of these determinations amounted to at most 3 in the fifth decimal ($\pm$ 0.00003), which may be said to be a very statisfactory result.

BUCHANAN'S determinations of the alkalinity coefficient, which we shall not discuss more closely here, showed that this only differed very little in Atlantic and Mediterranean water, although there was a difference that could be detected. What is of more interest to us, however, are the determinations of density, which as a rule referred only to the surface-water but yet also embraced a few samples from deep water. Of the two stations at which measurements were made under the surface, I may specially refer here to the one which has the greatest interest, as the observations there were made at greater depths where the conditions are independent of the variations in the surface-layer and can thus hardly be considered to have undergone great changes. From BUCHANAN'S values for the observed densities, which

were reduced to 15.56° C. I have calculated the density at 0° with the help of KNUDSEN's tables and therefrom the amount of chlorine, salinity and density at the observed temperature.

42° 56′ N. L., 8° 58′ E. L. (north of Corsica).

Depth (m.)	t°	$s\frac{15.56°}{4°}$	σ_0	Cl‰	S‰	σ_t
0	21.30	1.027316	29.650	20.42	36.89	25.87
100	13.10	28368	30.752	21.175	38.25	28.91
500	13.40	28667	31.065	21.39	38.64	29.15
1000	13.10	28635	31.032	21.37	38.60	29.18
1500	13.10	28613	31.009	21.355	38.575	29.16

As can be seen from the table, these values are a little greater than those we have found in the deep layers of water in the western basin, but the difference is not very great; nor is there any reason to expect that observations taken by different methods and reduced in a different way, would give precisely the same results as regards the absolute values; what is of far greater importance in this connection is, that the relative values show exactly the same variation in temperature and salinity with the depth, as we have found in our investigations, and we have here a confirmation of the high degree of accuracy in the areometric determinations of Buchanan — an accuracy, which seems to be at least as great as BUCHANAN indicates.

It is worthy of remark, further, that BUCHANAN's temperature observations also show, that the temperature has a maximum at a depth of 500 meters, thus at the same depth at which the highest salinity occurs. In other words, BUCHANAN has really found an intermediate maximum both for the temperature and the salinity, the situation of which, however, owing to the great intervals between the depths at which the observations were made, cannot be exactly determined. On the other hand, as the table shows, the decrease in the salinity from 500 to 1500 m. is so slight, that we can hardly conclude from such a single observation that this station gives a complete picture of the variation of the salinity with the depth, especially as the difference between the observed values for the density in deep water is not greater than the uncertainty given by Buchanan himself for the observed values.

It does not appear from the work cited, that Buchanan has ascribed any importance to the slight variation in density at 500, 1000 and 1500 meters, and if he has done so later I am not aware of it; in any case the general view has not been disturbed, which maintains, that below the surface-layer subject to variations with the season, there is an extensive layer with quite uniform conditions in regard to temperature and salinity. It is probable, however, that these interesting observations have quite escaped attention, which is in part due to the fact, that the results were published among a series of surface observations, and it is only explained in a foot-note that they belong to the depths mentioned. In any case they are given as surface observations in a later publication [THOULET 1905, p. 74], of the scientific results obtained by the PRINCE of MONACO and we are led in consequence to suppose, among other remarkable things, that the surface-temperature north of Corsica is 13.1° C. in September.

In 1902 the "Princesse Alice" made a series of temperature observations in the Mediterranean in the neighbourhood of Monaco and water-samples were taken from the depths at which the temperature was measured, down to a depth of about 1500 meters. The values obtained for the temperature lay about 13° C., but were not quite constant. The water-samples were investigated by Professor THOULET of Nancy [1902 a, p. 1459], who made partly pycnometer determination at 0° C., partly chlorine titrations. THOULET used the hydrographical tables, which had then just been published, for the reduction of his observations and his results are shown in the following table.

43° 36′ N. L., 7° 38′ 45″ E. L. 1485 m. 15. April 1902.

Depth meters	Temp.	σ_0	σ_t	Halogen contents (directly precipitated)	Cl reduced after Knudsen	Cl calculated from σ_0	S calculated from σ_0	Diff. $Cl_{\sigma_0} - Cl_{titr.}$
0	14.8	30.31	28.14	20.98	20.78	20.88	37.71	0.10
285	13.2	46	63	21.09	89	98	90	09
485	13.1	85	29.03	31	21.10	21.25	38.38	15
685	13.1	83	02	30	09	23	35	14
885	12.8	87	12	34	13	26	40	13
1085	13.0	86	07	34	13	25	39	12
1285	13.0	89	09	38	16	27	42	11
1485	12.9	80	03	31	10	21	31	11

As the table shows, neither the temperature nor the density (i. e. the salinity) is constant in the extensive bottom-layer, as had earlier been supposed to be the case and THOULET draws from this the conclusion, that this layer of water cannot be so much at rest as all the earlier investigators had imagined.

THOULET's observations, however, do not show any regular course in the dimensions measured, nor does THOULET give any explanation of how these differences can be imagined as arising and continuing. Compared with our observations also, the fluctuations of the temperature do not seem quite reliable, as the value 12.9° in 1485 meters' depth would lead us to suppose, that the temperature at great depths again decreases downwards, which is not the case.

Further, THOULET uses his titrations and density determinations as basis for a critical discussion of the hydrographical tables, which had just been published; the quantity of chlorine found from his density determinations by means of KNUDSEN's tables appears to have an almost constant difference of ca. 0.12‰ from the value found directly by titration and reduced with the help of KNUDSEN's tables. In a later work THOULET [1902 b, p. 14] and in collaboration with CHEVALLIER [1902, p. 1606] continues this investigation and comes to the result, that KNUDSEN's tables do not hold good completely for the Mediterranean water and as reason for this the author assumes, that the chemical composition of the latter is not the same as that of oceanic water, with the result that the relation between the amount of chlorine and the density is different from that holding for the oceanic water.

It was not improbable beforehand, that the Mediterranean might not follow the relations applying to the oceanic water, owing to the special conditions prevailing in the Mediterranean; it was conceivable, that the great amount of evaporation would lead to organic matter and inorganic, non-halogenic salts being left behind by the river water, so that the total quantity of salts and the density would not stand in the same relation to the quantity of chlorine as in the case of the oceanic water.

Thus, NATTERER found that variations in the chemical composition of the water could be detected at certain parts of the eastern Mediterranean basin, as the quantity of bromine varied somewhat, but this variation is very small, the amount of bromine found by NATTERER varying between 0.04 and 0.07‰; even if a similar variation were to be found in the western part of the Mediterranean, though we have no information of such, and it can hardly be the case (according to NATTERER the low value mentioned was only found in the Levant), yet it would certainly not give rise to anything like so great a disagreement as THOULET has found.

It might perhaps be said, that there is no reason to enter so fully into THOULET's criticism, as there were 2 samples from the Mediterranean among the water-samples examined in determining the constants of sea-water in addition to 1 from the Red Sea, and that, if the Mediterranean water had been essentially different from the oceanic water, this would have been revealed by marked differences between

the directly observed values and the values calculated from the smoothed formulae. It is certainly true, that the Mediterranean water shows relatively large differences between the value for σ_0 calculated from the observed quantity of chlorine and that obtained directly by pycnometric determination at 0°, but this only amounts to respectively 0.0052 and 0.0082 [KNUDSEN 1902, p. 157], whereas the difference found by THOULET amounts on the average to 0.17.

Considering the above table showing the results of the "Princesse Alice" from the neighbourhood of Monaco, we see, however, that the values calculated from σ_0 for the amount of chlorine lie between 21.21 and 21.27‰ for the deeper layers, values which lie very near to those found by us over the whole of the western basin. In 1910 we found everywhere values between 21.23 and 21.25‰ at depths of 1000 meters or more, and as there is hardly any reason to suppose, that the quantity of chlorine at great depths has greatly changed in the interval between THOULET's and our own investigations, it seems to me that THOULET's determinations of the density at 0° are good evidence, that the tables in question give the density at 0° with an accuracy which is as great as that which can at all be reached by chlorine titrations according to MOHR-BOUQUET DE LA GRYE's method.

As THOULET's determinations of the density thus agree with our chlorine determinations, we may suspect that the cause of the disagreement lies in THOULET's titrations. The method has not been so fully described as one would like, where it is a question of criticising a work so carefully prepared and carried out as the international determination of the constants of sea-water, but it seems from the description, that the method used was essentially the titration method of MOHR-BOUQUET DE LA GRYE, except that the titrated quantity of seawater was weighed. To the brevity of the description we may perhaps ascribe the statement of THOULET [1902 b, p. 13], that the silver nitrate solution was prepared by dissolving 47.936 gm. of $AgNO_3$ in 1 litre of distilled water at 15° C., and that 1 cm.³ of this solution thus contains exactly 0.047936 gm. of $AgNO_3$ and is just equal to 0.01 gm. Cl.

If the method really has been as described, it is an easy matter to show many, even very serious sources of error. In the first place, we must presuppose that the silver nitrate was absolutely pure and further, that none of it was dissociated by the light after solution; again, the distilled water was measured, and we must also reckon with an appreciable error here, but it is probably just as essential, that no attention was paid to the change in volume on dissolving; how much this amounts to, I do not know, but by analogy with the condition of other salts in dilute solution, we are certainly not permitted to ignore its amount.

THOULET's method of making the analysis was to weigh ca. 10 gm. of seawater and the volume of $AgNO_3$ solution necessary to precipitate the halogens in this was added from a burette, on which the amount used was read off. If now we calculate the amount of solution necessary for 1000 gm. of seawater and use the above value for its strength, we have at once the chlorine content of the sample in question, when this is defined in agreement with the method now generally used [1]. How THOULET could find use for a titration correction from KNUDSEN's tables, when he assumes that the solution has the strength mentioned, is not apparent from his work; it is possible, however, that a sample of normal water received from Copenhagen has been used to control the strength of the solution, but this is also rendered improbable by the statement of THOULET in this connection, that he found the same value as that given on investigating the halogen content of this sample of normal water. As we obtain no information regarding the manner in which such an absolute determination of the strength of the solution has been made, we may perhaps assume, that it has been done as above (i. e. assumed to be determined by the constituents of the solution), and it may therefore be regarded as a pure chance, that the determination has given the correct value. To make such a control determination of the normal water with a solution of so uncertain

[1] The weight of chlorine in 1 kg. of seawater, as the other halogens are considered to be replaced by the equivalent quantity of chlorine [Sörensen 1902, p. 98].

strength, seems to me analogous with, for example, controlling a carefully executed and reduced weighing of a certain quantity of water by means of an untested measuring glass.

Though THOULET's description of his titration methods can hardly be interpreted otherwise than as above, it is possible naturally, that its brevity has led me to misunderstand the method of determining the absolute values, but if the interpretation is correct, then the probability is, that the method gives too high values for the quantity of chlorine, since the silver nitrate solution owing to the increase in volume on dissolving the salt will be weaker than assumed. In the publication mentioned earlier THOULET [1905, p. 82] only gives the values indicated in the 5th column of the above-mentioned table for the quantity of chlorine and these are undoubtedly too high. That the quantities of chlorine given in the publication referred to are also too high in other cases, is clearly seen from the values given for the Bay of Biscay in 1903, which are 19.65—19.71 ‰ at depths of 3000—3500 meters; these are at least 0.2 ‰ too high.

Whether the above-mentioned systematic error in the determination of the chlorine arises from the cause indicated (a weaker solution than assumed owing to expansion on dissolving the salt) or is due to other factors, it may be taken as certain in any case, that this serious error really exists — an error which is possibly constant for a short series of experiments (that is, for all titrations made with the same solution) and perhaps for a longer series in the most fortunate case. We may regret, however, that such a doubt regarding the correctness of the methods used in hydrographical investigations, should have been put forward on THOULET's authority and on such a feeble basis, and that it has not been controverted sooner. This has not contributed to advance uniformity in the methods of working, which was one of the chief objects of the international cooperation and was intended to make all the results obtained directly comparable.

ALLEMANDET, who has continued THOULET's investigations, found some disagreement in his first series of experiments [1905 a] between the values for σ_0 determined by means of the pycnometer and those calculated from the quantity of chlorine, but in his next series [1905 b] ALLEMANDET found 0.00003 as the mean for the difference, which indicates, that observation errors have really been the disturbing factor in the original measurements. Lastly, the control determinations instituted by the Conseil permanent international pour l'exploration de la mer [RUPPIN 1910] must have removed all doubt regarding the relations found by KNUDSEN.

The oceanographic investigations carried out by WOLFENDEN [1909] in the North Atlantic within recent years, which have given such interesting results regarding the extension of the warm-water region to the west of the Straits of Gibraltar, also touch upon the Mediterranean, as some stations were taken in the Straits in 1904 and 1905, and in 1904 also a station inside the Straits in the Alboran Sea at 3° 41′ W. L., 35° 45′ N. L., 1463 meters. In the temperature measurements, however, no advantage has been reaped from the advances of recent years in this field. WOLFENDEN has used the Miller-Casella thermometers and Negretti-Zambra's reversible thermometers and remarks, that the readings of these do not differ by more than 2 to 3 tenths of a degree. In order that the temperature measurements in the deeper layers of the Mediterranean may give more information than that previously to hand, however, we must strive after greater accuracy in determining at least the relative values, and Wolfenden's observations of temperature in the deeper layers have not yielded anything new. At the station in the Alboran Sea (No. 44, 1904) decreasing temperatures were observed from the surface down to a depth of ca. 500 m., from 550 m. down to the bottom (1463 m.) the temperature was found to have the constant value 12.5°. At Wolfenden's St. 43 in the Straits of Gibraltar the same value, 12.5°, was found from 366 m. down to the bottom (914 m.).

It will be seen from the tables of our observations, that the temperature in the deep layers in the neighbourhood of the Straits of Gibraltar is not a little (0.3°—0.5°) higher than that found by WOLFENDEN and as there can hardly be any talk of such great variations of the temperature in the bottom-water,

there is reason to believe, that WOLFENDEN's thermometers have given too low values. For the salinity of the bottom-water in the Alboran Sea WOLFENDEN finds the constant value 38.62 ‰ in the layer of water in which the temperature is constant, a result which is more than 0.2 ‰ higher than what we have found in the corresponding layer everywhere in the western part of the Mediterranean. There is scarcely any doubt, that the salinities are throughout too high, which seems evident also from DICKSON's summary of the titrations carried out by MANLEY and the control determinations made by Prof. PETTERSSON of Stockholm; the average of the last-mentioned, from 7 observations, gives a salinity which is 0.25 ‰ lower than those of MANLEY [WOLFENDEN 1909, p. 98].

For a great number of years the German liners passing through the Mediterranean have been taking observations of the surface temperature as well as meterorological observations, and records of the currents so far as this could be done; for the years 1886—1902 this material, which is probably very heterogeneous, has been worked up and published by the Deutsche Seewarte [1905] in a very compendious and accessible form and it seems to be of considerable interest in hydrographical regards. For example, the observed directions of the wind may be considered better determined than will be the case at stations on land, where local conditions have so frequently to be taken into account, and these wind observations have naturally great importance in understanding the movements of the surface-water. Similarly, the observations of the surface-temperature give an important contribution towards the solution of the question regarding the vertical movements in the surface-layer, so far as this question can be dealt with when simultaneous observations of the density or salinity are wanting. On the other hand, the data regarding the direction and strength of the surface-currents must probably be taken with great reservation.

With regard to the currents of the surface-water, these observations naturally give nothing essentially new, but their great importance lies in the continuous observations of the surface-temperature, from which we obtain excellent information to help in solving the question of the variation of temperature at the different seasons of the year. As an example of this I may just mention, that it appears from the work, that whilst the increment of temperature from April to May is respectively 0.9° and 1.3° for the air and surface-water on the stretch from Gibraltar to Tunis, it is 2.5° and 1.8° respectively for the northern parts of the western Mediterranean. As we should expect, that the rise of temperature at this time of year would be greatest in the southern part of the basin, and as similar conditions do not prevail in the more easterly parts of the Mediterranean, the author is undoubtedly right in his conclusion, that this divergent condition is due to the influence of the Atlantic Ocean. Further, the time of occurrence of the highest and lowest temperature can be determined from this material; the maximum temperature falls in August, both for the air and water, whilst the minimum for the air occurs in January, but that for the surface-water in February.

Furthermore, in conjunction with observations in the deeper layers these mean values for the air and surface temperature are also of importance in a discussion of the vertical movements in the Mediterranean and we shall return to them later.

With regard to the movement of the water in the deeper layers, with exception of the above-cited conclusions of Professor THOULET, which are apparently based on errors of observation, this question has not yet been touched upon, but of recent years the vertical movements in the surface-layer have been the subject of active discussion. HANN [1908 a, 1908 b], on the basis of the Austrian observations of temperature in the eastern part of the Mediterranean, has put forward the view, that the vertical circulation only reaches to a depth of ca. 100 meters; from 100 to 500 meters the distribution of temperature is the result of the conduction of heat which has been going on for hundreds or thousands of years, and for the extensive layer from 500 meters to the bottom (down to 4000 meters) HANN assumes that the temperature is almost quite constant (13.5°—14° C.), possibly subject to secular variations.

KRÜMMEL [1907, p. 497, 1908] places the boundary for the vertical circulation considerably deeper,

for the western basin of the Mediterranean at ca. 300 meters (somewhat deeper than CARPENTER) and for the eastern basin at ca. 500 meters; thus, in opposition to HANN he concludes, that the water-layer from 100 to 500 meters takes part in the vertical movement, and that in winter this is continued down to the greatest depths [1908, p. 323], so that we have a constant temperature in a vertical direction (in agreement with MAKAROFF [1894, p. 199]).

Whilst the Atlantic Ocean has for may years been the special field of work of the PRINCE of MONACO and only a few scattered observations have occasionally been made in the Mediterranean, recent years have seen a change and the steamer "Eider" has been making regular and continuous investigations in the neighbourhood of Monaco. It would be difficult also to imagine a more favourable basis of operations than Monaco for the solution of the many interesting questions regarding the hydrography of the Mediterranean, for the various, typical layers of water are represented here at quite a short distance from land. A list of the results for the years 1907—1909 has been published by J. RICHARD and L. SIRVENT [1909], from which it appears, that extensive oceanographic investigations of every kind have been made in the years mentioned, but of the hydrographical investigations only the temperatures have been published and these only extend down to depths about 200 meters in the first years, which is probably due to the prevailing assumption, that the water at greater depths is homothermal and homohaline. Nevertheless, this material is of great value, as we can learn from it what changes occur in the upper water-layers, both as regards horizontal currents and the interaction between atmosphere and surface of the sea and the consequent vertical movements.

On the basis of the investigations in 1907 and 1908 Professor NATHANSOHN [1909] has written an interesting paper, whose greatest importance probably lies in the investigations made with regard to the plankton; but regarded from the purely hydrographical side it also gives a valuable contribution towards the solution of the important question of the vertical circulation in the uppermost water-layer. From the temperature observations made at intervals of ca. 14 days and the chlorine titrations at two stations in the neighbourhood of Monaco, NATHANSOHN finds [1909, p. 23], that cooling at the surface has led to the vertical movement reaching a depth of ca. 150 meters at the end of January 1908, the whole layer of water from the surface down to this depth being both homothermal and homohaline; in the beginning of February the further progress of the movement downwards stops owing to milder weather, but at the end of February it begins again and is continued until the middle of March, at which time the vertical movement has progressed down to a depth of ca. 225 meters.

NATHANSOHN calls attention to the fact, that the water-masses in which these investigations were made, in spite of the cooling, are yet considerably lighter than the bottom-water in the western basin of the Mediterranean, their chlorine content being ca. 21.10‰, and that, consequently, the vertical circulation in question will not be able to touch the true bottom-water, the chlorine content of which is considerably greater, though the value 21.30—21.35‰ given by NATHANSOHN is a little too high. In agreement with KRÜMMEL, NATHANSOHN concludes, that there is a less salinity at these stations, owing to their short distance from the coast, than there would be further out in the Balearic Sea, and the author puts forward the question whether the surface-water on cooling may not reach just as great a density as the bottom-water in the region between the Balearic Isles and Sardinia-Corsica, where the surface-salinity may be considered as least influenced by the coastal water. In this case the bottom-water would take part in the convection currents starting from the surface.

This view was fully confirmed even before it was put forward, as DR. SCHMIDT found almost the same density from the surface down to a depth of 2000 meters at the end of January 1909 to the west of Corsica. It appears from our later investigations, however, that this phenomenon is not restricted to this one region and NATHANSOHN has also shown this [1910, p. 12] almost simultaneously and independently of us; at the PRINCE of MONACO's station 2809 between Monaco and Corsica, (43° 22′ N., 7° 35′ E.) investigated

on 7. April 1909, he found the same salinity at the surface and bottom (2213 m.), whilst the temperature was 12.67° at the surface and 12.97° at the bottom.

I may remark here, that when the convection currents had reached to a depth of 150 meters in January, as in the above case, there was reason to expect, that in the course of the next two winter months they would continue down to greater depths than 225 meters, and if this was not the case, then the temperature of the air at this time has possibly been higher than the normal, but it is also probable, that the stations investigated lie too near the coast to give reliable results in this regard. It is well-known, that the lighter coastal water will tend to spread outwards from the land in order to produce equilibrium, whilst it is partially replaced by an inflow to the water-layers below, thus that the effect of the cooling near the coast is not accumulated at the one place; the thickness of the water-layer which has been cooled down, is in fact reduced by the outward flow of the coastal water and the compensating rise of the boundary towards the layer with the higher salinity below. In any case there can be no talk of a welling up of the surface-water near the coast from the action of the winds, as the work of the Deutsche Seewarte cited above shows, that in winter the winds over this part of the Mediterranean blow more frequently offshore than towards the land.

Since the autumn of 1909 these observations at stations in the neighbourhood of Monaco have been continued down to the greatest depths and the results may be looked forward to with the greatest interest, as they will certainly afford an answer to the important question of the changes which occur in the deeper layers in the course of the year, a question that cannot be solved by an expedition with a limited time for investigation at its disposal.

B. The "Thor" Expeditions in the Mediterranean.

I. The temperature observations and water-samples.

On both cruises of the "Thor" the water-samples from deep water were exclusively taken with Pettersson's insulated water-bottle; at less depths a sinker was used as a rule to close the bottle, but for great depths a water-bottle with propeller was generally used; this closed automatically when hauling-in began. The wire for the water-bottle was of galvanized steel, 3 mm. in diameter, from the firm Felten and Guilleaume, Mühlheim, Germany, with a breaking strength of about 200 kg. per square millimeter. This wire, which I had used for several years and found completely satisfactory, gave us several unpleasant surprises on the summer cruise of 1910. On one occasion, for example, the wire broke when hauling in and a water-bottle with about 2000 meters of wire went to the bottom. Whether the wire delivered to us in 1910 was of inferior quality, I am unable to say; possibly the high salinity of the water in conjunction with the high temperature when not in use has caused it to rust quicker than under the earlier conditions when I used it.

The depth to which the water-bottle was sent down, or rather the length of wire out, was measured on a meter-wheel (1 meter in circumference) attached to the davit through which the wire ran overboard (see fig. 7, p. 11). It is obvious, that the two lengths are not identical and that the measured length of wire only gives an upper limit for the depth in which the water-bottle is; it is only when the wire is quite vertical in the whole of its length, that the bottle reaches the depth read off on the wheel; in all other cases the bottle has not been so deep down. The ship was manœuvred so as to have the wire as far as possible vertical and small distances from the vertical could be corrected by measuring the angle of divergence.

In registering the depth it is impossible to avoid errors completely, however, as the wire may very often have a bend in it down in the water though hanging vertically at the surface. A well-marked case of this kind occurred at St. 98 in the Straits of Gibraltar, where the current was running eastwards at a rate of at least 4 miles per hour. The ship was thus drifting eastwards, but at the same time there was a fresh to stiff wind from the east, so that the easterly drift of the ship was less than that of the surface-water; the latter consequently carried the wire with it at a considerable angle so long as the bottle was being let down, but when hauling-in began and the strain on the wire increased, the latter became straighter and even showed a strong inclination towards the west in the case of the greater depths (300, 500 and 700 m.).

Here we should only increase the error in registering the depth if we kept the uppermost part of the wire vertical when letting it down, and it is also very difficult to form even an approximate estimate of the difference from the desired depth at the time when the measurements are taken. It is only when these have been made and the samples analyzed, that we can obtain an idea of the length of wire which has been under the influence of the currents in the different layers of water and thus of the amount of sheer. As a rule the error in the depths recorded for the water-samples will not exceed 1 to 2 per cent

for depths of 200 meters or more, except in the very unfavourable cases, as in the above-mentioned example, where a very strong surface current ran in the one direction, whilst below this a strong under-current ran in the opposite direction.

The water-bottle was hauled in as a rule by means of a steam-winch specially designed for the purpose, but where the depth was not great a hand-winch was sometimes used. This was fixed on a special davit and its drum could take 200 meters of the above-mentioned wire. In the case of the steam-winch the wire was generally hauled in at a rate of about 200 meters per minute, which was far below the maximum speed. In a few cases a heavier steel-wire was used on the last part of the cruise; this was worked on one of the drums of the trawl-winch and could be brought up at a rate of about 100 meters per minute. As the heavier wire was run out aft and the lighter forwards on the foredeck, both could be worked at the same time; similarly, the hand-winch and the small steam-winch could be worked together.

As already mentioned, it was sometimes necessary to manœuvre the ship during the work, so as to prevent the wire from going down obliquely as the result of the drift of the ship with the wind or surface-current, but as we were favoured with specially good weather on nearly the whole of the 1910 cruise, the engines were stopped as a rule while the measurements were being made. Frequently also a dredge was put out before the measurements were begun and only taken in when the latter were completed; this acted as a drag on the ship and reduced its drift whilst the hydrographical observations were in progress.

The small steam-winch used for hauling-in the water-bottle was also employed in working the lead and gave reliable results for depths less than 2000 meters; the lead used weighed 20 kg. and a steel spring on the davit marked the moment when the lead touched the bottom. When the weather was very still, this winch could also be used for soundings at somewhat greater depths, but when there was any sea or swell and the ship rolled, the irregular pulls on the wire led to uncertainty and when a length of 2000 meters or more was out under such conditions, the weight of the wire was excessive by comparison with that of the lead. Under these circumstances a Lucas' automatic sounding machine (large model) was employed and worked on a steel wire (piano wire) of about 1 mm. in diameter, made by the Great Telegraph Construction and Maintenance Company, London. Some old cannon balls were used as slip-leads and a special slip-mechanism designed by Capt. Hansen of the "Thor" acted most successfully. The results obtained by means of Lucas' sounding machine were completely satisfactory, even at the greatest depths where it was used; the deepest sounding was taken at St. 144 in the middle of the Ionian Sea, where a depth of 3340 meters was measured.

During the winter cruise of 1908—1909 the deep-water thermometer attached in Pettersson's water-bottle was exclusively used in determining the temperature. As is known, the volume of water enclosed in the bottle alters its temperature during the hauling-in, owing to a reduction of the pressure as the bottle approaches the surface, and this reduction of the pressure is accompanied by an expansion of the water. The expansion occurs without the enclosed volume of water being able to receive or lose heat (adiabatic expansion) and, consequently, is accompanied by cooling of the water contained in the bottle. The readings of the thermometer in the water-bottle must therefore be corrected for this change of temperature, and for this purpose the data calculated by Ekman [1905] on the basis of Tait's experiments were used. It then proved, that the temperature in the deeper layers, after reaching a minimum at a depth of about 1000 m., rose as a rule down towards the bottom. This result might seem improbable, as the salinity was almost constant at these depths and seemed rather to decrease where any variation could be detected.

There might be reason to suspect, therefore, that the values calculated by Ekman for the temperature correction for adiabatic expansion were too high, or that this correction did not increase so greatly

with the depth (pressure) as appeared from EKMAN's tables. I endeavoured therefore to investigate the question more closely, a matter of some difficulty, as the only source mentioned by EKMAN was "deduced from TAIT's experiments", whilst it proved on going through these, that they embraced several series of experiments independent of one another. So far as the absolute values are concerned, these series do not agree very well, though the relative values for the compressibility are in good agreement [TAIT 1889, 1895]. As TAIT has not removed this slight uncertainty in the value for the compressibility by later experiments, so far as known to me, I came to the result, that this question could be solved most easily and with the greatest certainty by means of experiments in the waters in question.

The irregularity in the distribution of the temperature cannot arise from faulty insulation of the water-bottle, as the temperature in the whole of the layer investigated only varies a little and the difference between the temperature of the water enclosed in the bottle and that outside is thus very small. Further, there were cases in which any change of temperature in the water-bottle would tend to cool the water contained in it during hauling in.

To determine accurately, that this rise of temperature towards the bottom in the greatest depths really existed aud to determine further the value of the correction for the adiabatic expansion on hauling up, reversible thermometers were used extensively on the cruise in 1910 to control the results of the water-bottle thermometer. This was also considered necessary, to make sure that the insulation of the water-bottle was sufficient to keep out the heat during the passage through the very warm surface-layer of the summer season.

Many series of comparative observations were made with the reversible thermometer and the water-bottle thermometer, all of which showed good agreement between the two. It thus proved, that the insulation of the water-bottle was completely satisfactory and that the readings of the water-bottle thermometer, after being corrected for temperature changes on hauling in, were quite trustworthy. After this had been determined, the thermometer of the water-bottle was frequently used alone down to depths of 2000 m., which meant a great saving of time in making the observations. On the basis of these control determinations, further, I am inclined to believe, in opposition to the Norwegian hydrographers [HELLAND-HANSEN and NANSEN 1909, p. 33], that the temperatures obtained in this way are just as reliable as those of the reversible thermometers; for a water such as the Mediterranean, where the temperature gradient is so slight through a very thick layer of water, I would even prefer the deep-water thermometer to the reversible thermometer.

In the first place, even the best reversible thermometers may give serious, chance errors, which are readily detected naturally so that they lead to no mistakes; but if large chance errors can occur, we have no guarantee that there may not be small, and the observed reading taken to be trustworthy when it really is not so. Further, when the reversible thermometer is used under conditions such as are found in summer in the Mediterranean, the temperature of the thermometer itself rises greatly at the moment it comes up, so that a reading of the thermometer, taken immediately after, is far from giving the desired accuracy; we cannot suppose, namely, that the separated column of mercury has the same temperature as the correction thermometer, which is attached in order to determine the temperature at which the reading is made. If we use two reversible thermometers alternately, so that the temperature of the broken-off mercury column may become constant before the reading, we may possibly lose that certainty in the small differences between the readings of the two thermometers for two successive depths which we obtain by using the same thermometer at both depths, but the use of a single thermometer prolongs the time of a single observation by 6—7 minutes — which is by no means without importance when so many observations are taken as on the "Thor" Expedition in 1910 — without in any way giving greater accuracy than the more rapid and just as trustworthy method of using the deep-water thermometer in the insulated water-bottle.

On the cruise in 1910 two reversible thermometers of RICHTER-NANSEN construction were used, the one adjusted at the Physikalisch-technische Reichsanstalt of Charlottenburg, the other at the Central Laboratory in Christiania. The last was fixed in EKMAN's reversible apparatus for attachment to PETTERSSON's water-bottle, the first was attached to an older reversible apparatus after MAGNAGHI, so that both could be used at the same time. It proved, however, that the thermometer in EKMAN's apparatus frequently gave quite absurd results, so that the control obtained by using the two reversible thermometers was of doubtful value; on the other hand, the thermometer in MAGNAGHI's reversible apparatus worked very satisfactorily and it was only on quite a few occasions that the chance errors occurred which are unavoidable in using reversible thermometers. How far the great uncertainty in the first thermometer was due to the thermometer itself or to the reversible apparatus, I cannot say, as I did not make the test necessary to determine this, namely, to change the thermometers, but I am inclined to believe that the reversible apparatus was at fault; its construction at any rate is far from satisfactory, as the steel spring on the axle of the apparatus proved to be of very bad quality and lost its resilience after a short time in use, so that it straightened out when the strain necessary for turning the thermometer was put upon it.

The results of the comparison of the data obtained from the water-bottle thermometer and the reversible thermometers confirmed on the whole the correctness of EKMAN's tables, though it proved that the correction increases somewhat less with the pressure. For lesser depths (100—800 meters) there is no regularity in the differences between the values obtained from the two different methods; the differences are on the whole small (of the same order as the observation errors) and change sign without any regularity, which means, therefore, that down to a depth of 800 meters EKMAN's correction tables can be used without any modification. For this reason the accompanying table only includes the observations from 1000 meters and greater depths; the first column gives the number of the station (for position see table of the stations), the following columns show the temperatures observed at the depths indicated, t_E showing the readings of the water-bottle thermometer corrected for the adiabatic cooling from EKMAN's tables after the thermometer's own corrections had been applied, t_r representing the readings of the reversible thermometers corrected naturally both for the instrument's own error and for the temperature change in the separated column of mercury; lastly, d is the value (in hundredths of a degree) for the reversible thermometer minus "EKMAN", thus the amount by which the temperatures obtained with the water-bottle and corrected from EKMAN's tables, must be corrected.

As the table indicates, the agreement in the differences between the values obtained according to the two different methods is quite satisfactory, when the two stations (81 and 87) in the Atlantic are

Table I.

	1000 m.			1200 m.			1500 m.			2000 m.			2500 m.			3200 m.		
	t_E	t_r	d	t_E	t_r	d	t_E	t_r	d	t_E	t_r	d	t_E	t_r	d	t_E	t_r	d
St. 81.....	10.84	10.84	0	..	..	..	6.99	6.97	— 2	[4.27	4.20	— 7]	..	..	.	..	..	..
- 87.....	12.01	12.00	— 1	11.63	11.59	— 4	10.87	10.82	— 5	..	..	..	..	..	..	..	..	..
- 107.....	12.88	12.88	0	12.90	12.89	— 1	12.93	12.93	0	13.02	12.99	— 3	..	..	..	.	.	..
- 115.....	..	..	..	..	..	..	..	..		12.96	13.00	+ 4	13.03	13.03	0	.	..	.
- 116.....	12.87	12.86	— 1	..	..	..	12.93	12.92	— 1	..	..	..	13.05[3]	13.02[3]	— 3	.	.	.
- 118.....	..	..	..	..	..	..	..	..	..	13.03	13.01	— 2	13.10	13.07	— 3	..	.	..
- 120.....	..	..	..	..	..	..	..	..	..	13.03	13.01	— 2	13.08	13.06	- 2	..	..	..
- 122.....	12.92	12.91	— 1	12.94[1]	12.93[1]	— 1	..	..	..	..	..	..	..	..	..	..	..	..
- 129.....	13.44	13.42	— 2	13.34	13.32	— 2	13.23	13.21	— 2	13.21	13.18	— 3	13.24	13.20	— 4	13.35	13.29	— 6
- 144.....	13.58	13.58	0	..	..	..	13.55	13.55	0	13.58	13.56	— 2	13.63	13.60	— 3	13.74	13.69	— 5
- 145.....	..	..	..	..	..	..	13.53	13.52	— 1	13.52[2]	13.51[2]	— 1	..	.	.	..	..	..
- 156.....	..	..	..	..	..	..	..	..	..	13.65	13.62	— 3	13.73	13.69	— 4	13.81[4]	13.76[4]	— 5
- 160.....	..	..	..	..	..	..	..	..	..	13.65	13.61	— 4	13.73	13.71	— 2	13.82[4]	13.78[4]	— 4

[1] 1250 m. [2] 1800 m. [3] 2400 m. [4] 3000 m.

excluded; in the case of St. 87 especially the high value for d at 2000 m. is probably due to the innermost chamber of the water-bottle receiving a little heat, owing to the great difference in temperature between it and the water-layers through which the bottle passed. It appears further from the table, that d has the value — 0.05 for depths of about 3200 m., — 0.03 for 2500 m. and — 0.02 for 2000 m., whilst it is almost — 0.01 for 1000 m., from which we see, that the correction for the change of temperature under adiabatic expansion increases somewhat less with the pressure than EKMAN indicates. In the cases where observations were taken at 2000 m. without simultaneous use of the reversible thermometer, the reducing values calculated by EKMAN have therefore been corrected by — 0.02° and for the depths 1000—1500 m. by — 0.01°; the temperature observations from the winter cruise of 1908—09 have also been corrected to the same extent. The values thus obtained for the temperature must therefore be considered accurate within the limits ± 0.02°, except for the surface-layer with its steep temperature gradient in a vertical direction, for which the temperature has frequently been measured with an accuracy of only 0.1°.

II. The salinity determinations.

In a few cases the density has been determined by means of the areometer, with subsequent calculation of the salinity from KNUDSEN'S tables; but these cases were restricted to a few less important stations in the Dardanelles and Bosphorus, where the salinity varied very greatly with the depth, at certain places over 1 ‰ per meter. Here an areometer of normal glass from STEGER of Kiel was used and the data were corrected by titration; in the tables of the observations the salinities obtained in this way are only given to 1 decimal in contrast to the results determined by chlorine determinations, and the accuracy could hardly be greater than ± 0.1 ‰.

At all the stations in the Mediterranean, on the other hand, the salinity was determined by titration after the method of MOHR — BOUQUET DE LA GRYE; for the winter cruise of 1908—09 the water-samples were kept in medicine bottles of 200 cc. capacity and titrated later at the Hydrographical Laboratory in Copenhagen, so that some of the samples were kept for about 4 months before titrating. Nevertheless, no changes worth mentioning seemed to have occurred in the salinity from evaporation through the cork stoppers. This is seen from the fact, on the one hand, that there is no great break in the relative values and on the other, that the absolute values agree well with those found on the summer cruise of 1910.

As the investigations in 1910 were made at quite the warmest time of the year, the conditions were much more unfavourable to keeping the water-samples and titrating them later on land. As I desired, further, to reach the greatest possible accuracy, I undertook all the titrations on board myself, so that each sample was as a rule analyzed within a week after it was taken. On the cruises to Iceland and Greenland, in which I had taken part earlier, I had always made the titrations on board and had come to the conclusion, that in a well-equipped laboratory with careful arrangement of the apparatus and practice in working under such conditions, just as good results could be obtained as in a laboratory on land. And I am not clear as to the nature of the advantages referred to by HELLAND-HANSEN and NANSEN in their work on the hydrography of the Norwegian Sea [1909, p. 57], when they say, that investigations on land have more favourable conditions for the attainment of exact results, nor are these advantages named. On the other hand, when the samples are kept for analysis on land there is the danger, that the salinity is increased by evaporation of the water through the cork.

When the titrations are carried out on board we have the very distinct advantage, that accurate data regarding the distribution of the salinity are already to hand before the end of the cruise and we are thus able to make supplementary investigations, if these should prove necessary. The results obtained

from the ordinary areometric determinations on board are as a rule not sufficiently accurate for the waters in which the variations of the salinity are but small.

The criticism passed by the authors mentioned on my earlier titrations on board ship seems to me somewhat remarkable; that an appreciable error is introduced into the results of titrations, when the analyzed sample and the normal water have a different temperature, should be so well-known that time and energy need not be wasted in saying so and the fact, that we have a method of titrating a water-sample on board, affords no reason whatsoever for assuming, that samples of cold bottom-water actually have been titrated before they have stood long enough to have the same temperature as the normal water. I am hardly alone in thinking that, if these authors were unable to find any other form for their criticism, they should rather have dispensed with stating it. When the two Norwegian authors say (p. 33), that they know the distribution of the salinity in the Norwegian Sea beforehand better than other investigators are able to determine it, we cannot but wonder at their possession of previous knowledge!

For the titrations a KNUDSEN's pipette with a capacity of ca. 15.5 cc. was used and the strength of the silver nitrate solution was so regulated, that the volume required to precipitate the halogens in the above quantity of seawater was almost twice the quantity of the chlorine in the sample (e. g. 42 cc. of $AgNO_3$ solution when the quantity of chlorine was 21‰). About 8 litres of the solution were prepared at one time and the weighing of the $AgNO_3$ and measuring of water necessary for this purpose could be done with sufficient accuracy on board ship, so that the strength of the solution lay within the interval for which the titration corrections are found in KNUDSEN's tables. The strength of the solution was determined naturally by titrations of normal water and a new solution was allowed to stand for at least one day before it was used.

The burette employed for all the samples from the Atlantic and Mediterranean was spherical in shape with three-way stopcock above; but for the fresher samples (Black Sea and surface-water of the Sea of Marmora) a cylindrical burette was used. A spherical burette has the very great advantage, that the adjustment at the 0 mark proceeds automatically without loss of time, but it possibly requires more frequent cleaning than an ordinary burette, though the difference is hardly appreciable, when the tap is well ground and only a small amount of grease is required to keep it tight, yet easily movable.

The spherical burette was divided from 18—25, each division representing 2 cc. and its length about 4 cm.; the interval was divided into tenths, and each of these halved; further, all the dividing lines were so long, that they stretched over at least half the circumference of the measuring tube, so that the readings were free from parallax errors and could be taken with an accuracy of 0.02 cc., corresponding to 0.01‰ chlorine.

In the titrations of the very uniform bottom-water, where the highest degree of accuracy was required, the burette reading was frequently taken with an exactness of 0.005; 3 decimals are sometimes given also for the quantity of chlorine, where this is derived from the average of 2 titrations which differed by 0.01 from one another. It cannot be assumed, naturally, that the values for the quantity of chlorine have been determined with so great an accuracy as this, as we must also take the other unavoidable sources of error into account, such as the running-off error both from the burette and pipette, and further the error arising from the estimate of the colour-change.

The endeavour was made to reduce all these sources of error to the least possible by making each single titration as far as possible under the same external conditions, and I am inclined to believe, that the error in the single determination is somewhat less than that given by BJERRUM [1904] in his work on the accuracy, which can be attained by means of this titration method, when the measurement of the sea-water sample is made with a KNUDSEN's pipette. This greater accuracy has been attained by the use of the spherical burette with three-way stopcock, through which the error of adjustment is completely avoided

and the running-off error reduced; lastly, all the readings which are of greatest importance are taken at very nearly the same place on the burette, so that the error in the relative values at least is reduced. It appears from the large number of repetitions which were made on the cruise in 1910, that the difference between the single repeated values does not as a rule exceed 0.01, and the relative values for the quantities of chlorine, which are in the neighbourhood of 21.25‰, can therefore be taken as determined with an accuracy of ± 0.01‰.

The error in the absolute values is naturally somewhat greater than in the relative, though it can scarcely exceed ± 0.01‰ to any essential extent (corresponding to an error in the salinity of ± 0.02‰), and the error in the tabulated results for the salinity found from KNUDSEN's tables will scarcely exceed ± 0.03‰.

As will be seen from the tables showing the results of our observations, no change in the quantity of chlorine with the depth can as a rule be detected for the great depths within the same, naturally limited region of the Mediterranean, even though the greatest care was used. As the observations of 1908—1909 showed no distinct variation either in a horizontal direction, I made the titrations of the deeper samples (2000 m. and more) in the following manner. At the different stations the titrations were made in a definite order — from surface to bottom or the reverse — and as soon as the pipette was full, the bottle was carefully corked and kept until a large number of samples had been collected from the deep water. Thus, in the western basin of the Mediterranean samples were kept from all stations, where the depth was 2000 m. or more, from Gibraltar until the first series of investigations in the Tyrrhenian Sea was concluded. The titration of all these samples was then made in succession on the same day and with one and the same silver nitrate solution, which for most of the samples was different from that used in the first titration. The samples from 2000 m. and more from the eastern basin of the Mediterranean, on the route from Malta to Smyrna, were preserved and titrated anew in the same manner. In the accompanying table II the values for the quantity of chlorine obtained from the first titration are given under Cl I; these titrations were made within a few days after the samples were taken; Cl II shows the results of the second titration, whilst the column d gives the difference.

Table II.

Station	Depth	*Cl* I	*Cl* II	*d*	Station	Depth	*Cl* I	*Cl* II	*d*
107	2000	21.24	21.25	— 0.01	144	2000	21.39	21.39	0.00
112	2000	23	24	— 01	—	2500	39	39	00
115	2000	25	25	00	—	3200	39	40	— 01
—	2500	24	24	00	145	1800	385	38	+ 005
116	2400	245	235	+ 01	152	2000	39	38	+ 01
118	2000	25	255	— 005	156	2000	39	39	00
—	2500	25	25	00	—	2500	40	40	00
120	2000	245	235	+ 01	—	3000	40	40	00
—	2500	24	24	00	158	2000	385	39	— 005
129	2000	27	27	00	160	2000	41	395	+ 015
—	2500	26	26	00	—	2500	40	40	00
—	3200	27	26	+ 01	—	2975	40	40	00

We learn from this table, in the first place, that no appreciable amount of water had evaporated through the corks, though the samples first taken had been kept for 17 days, and in the second place, that MOHR's titration method does not enable us to see, whether the quantity of chlorine follows any regular course at depths of 2000 m. or more; this quantity seems to be constant, both vertically and horizontally in the same regions, within the limits of accuracy we can expect from the method, namely ± 0.01. As this titration method readily showed variations in the quantity of chlorine at depths from 400

to about 1000 meters, it seemed reasonable to suppose, that differences might also be found in the deepest layers and thus to suspect, that the constant values were merely due to the insufficiency of the method for the investigation of this water-layer.

This unexpected result induced me to keep some water-samples for analysis after the return to Copenhagen. I had made no preparations for this eventuality, however, and was therefore obliged to keep the samples in ordinary 200 cc. bottles carefully closed with paraffined corks and the necks of the bottles afterwards dipped in melted paraffin. The samples were taken as late as possible before leaving the region the series was to represent, so that the interval until analysis might be as short as possible. Unfortunately, however, I was not successful in obtaining a chemist to undertake the work immediately on the return of the Expedition and it was not until the spring of 1911 that these samples were investigated. The analyses were made by Mr. Bjørn-Andersen (cf. his paper No. 3 in the present Report),and his results are given under Cl_{B-A} in table III; those marked Cl_N give the results obtained by myself by titrations on board.

Table III.

Station	Depth	Cl_{B-A}	Cl_N	Diff.
160	2000	21.399	21.41 [1]	— 0.011
	2500	400	40	000
	2975	403	40	+ 003
186	600	432	44	— 008
	800	411	42	— 009
	1000	410	42	— 010
	1250	401	415	— 014
	1500	399	41	— 011
195	800	341	—	—
	1000	319	31	+ 009
	1250	297	—	—
	1500	289	29	— 001
	2000	268	27	— 002
206	600	262	245	+ 017
	800	250	235	+ 015
	1000	248	24	+ 008
	1250	250	24	+ 010
	1500	260	245	+ 015
	2000	254	24	+ 014
	2500	250		+ 010

[1] A second titration of this sample gave $Cl = 21.395$ (see Tab. II).

It appears from this table, that the agreement between the relative values for the same station is extremely satisfactory, and that the results of my own titrations are fully confirmed, namely, that there is only an extremely small variation in the quantity of chlorine at great depths, but that the depth at which the constant value begins, varies from the one basin to the other. At St. 206 in the Balearic Sea there is a suggestion of a secondary maximum about 1500 m., but it is not very probable, that it occurs everywhere in this basin.

III. The Black Sea and Sea of Marmora.

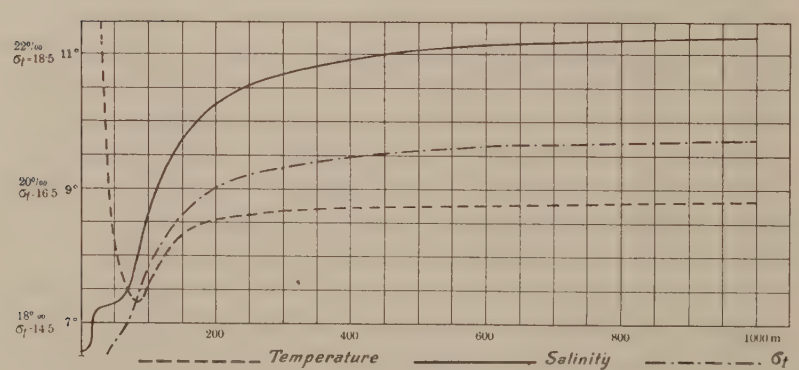

Fig. 1. (St. 172).

The two stations which were taken in the Black Sea afford a typical picture of the interesting and extremely characteristic conditions occurring there. From the observations at St. 172 and from the accompanying curve, fig. 1, it will be seen that the temperature decreases very greatly from the surface downwards and assumes its lowest value, ca. 7.3° C., at a depth of about 80 meters; from this the temperature slowly increases down towards the bottom, without being quite constant however. The salinity is constantly at ca. 17.6 ‰ from the surface to about 20 meters, where it shows a sudden rise to 18.2 ‰ and this value remains practically unchanged down to between 50 and 75 meters, after which the salinity increases more strongly down to

300 m.; from this depth the increase proceeds comparatively slowly though the rise of salinity is distinct. Between 17.5 and 20 m. we notice that there is a considerable rise especially in the temperature but also in the salinity, whilst both are fairly constant in the layer above. This constant value indicates, that owing to concentration of the surface-water on evaporation this layer has been subject to vertical currents produced by a disturbance of the equilibrium of the surface-layer (increase of the density of the surface-water through evaporation). It is seen also that the density is constant down to about 20 meters, at which depth it rises suddenly and strongly.

St. 173, about 2 miles from the mouth of the Bosphorus, shows almost the same condition for the uppermost layer as was found at the deeper station in the Black Sea; here also there is a well-marked temperature minimum (8.55° at a depth of 40 meters), but in the neighbourhood of the bottom, at a depth of 60 m., the temperature is specially high, namely 15.32°, and the salinity is even 36.49 ‰, that is to say, we meet here a layer which almost unmixed has flowed through the Bosphorus from the intermediate layer in the Sea of Marmora. This layer, which is certainly very thin, has almost twice the density of the bottom-water in the Black Sea; it will consequently move down rapidly into the depth of the Black Sea and become mixed with the water-masses there. At the deeper station No. 172, lying 22 miles from the mouth of the Bosphorus, the influence of this salter water cannot be shown directly, but the deepest sample was taken at a considerable distance from the bottom and a somewhat higher salinity may possibly occur near to this.

These two stations give an excellent confirmation of the earlier investigations in the Black Sea. Makaroff had made a number of hydrographical observations in the Black Sea after 1880, but the principal investigations were carried out in 1890—92 by Spindler, Wrangell and Lebedinzeff, and the most remarkable of their results was, naturally, the discovery of considerable quantities of hydrogen sulphide in the extensive layer of bottom-water. Without entering closely into these results I may just mention, that this occurrence of hydrogen sulphide is so marked, that all the water-samples at St. 172 from the bottom up to 200 meters had a penetrating smell of hydrogen sulphide, at 150 m. this smell had disappeared, and as the tables of the observations show, there was a small quantity of free oxygen at a depth of 150 m., the relative amount of oxygen being 2.4 %. According to Lebedinzeff also the hydrogen sulphide appears between 150 and 200 m. and the amount increases with the depth; as example I may cite the following values, which show the hydrogen sulphide in cc. per litre of seawater at the depths mentioned [Lebedinzeff 1893, p, 426].

183	366	1737	2166 meters
0.33	2.22	5.55	6.55 cc. H_2S

That the quantities of hydrogen sulphide are very considerable, is also evident from the fact, that the water-samples intended for the chlorine determinations became milky from the separated sulphur after standing a couple of days; the smell of hydrogen sulphide then naturally disappeared.

From the considerable number of temperature observations made in 1890 and 1891 in the deep water of the Black Sea, Spindler and Wrangel found [1899, also Woeikow 1891], that there is always a temperature minimum at a depth varying from 45 to 90 meters, and that this minimum occurs nearer to the surface in the middle of the basin than in the neighbourhood of the coasts; this minimum value is lower in the eastern than in the western part, but in general lies in the neighbourhood of 7°; from 200 to ca. 2000 meters the temperature rises from ca. 8.7° to 9.1°. For the surface-water the authors mentioned find a salinity of ca. 18 ‰, which increases down to ca. 700 meters, after which they find fairly constant values lying between 22.3 and 22.5 ‰. The agreement of these results with ours is thus extremely satisfactory and the explanation of the peculiar hydrographic conditions in the Black Sea is also given by the Russian authors (see later).

The hydrographical conditions in the Sea of Marmora are illustrated by the accompanying curves, figs. 2 and 2a, which represent the conditions at St. 170 in the eastern part in the neighbourhood of Prince Islands. The salinity at the surface is 21.51 ‰ and is very constant down to 10—15 meters; from there it increases rapidly down to 30 m. (the increase is almost 1 ‰ per meter), where the salinity is 37.47 ‰; the increase with the depth then becomes small comparatively, and from 100 to 1200 m. the value is constant, ca. 38.46 ‰, possibly with an indication of a maximum between 100 and 150 meters. At St. 175 in the western part the distribution of the salinity is almost the same; at the surface the value is only 0.2 ‰ higher, and the great increase begins at very nearly the same depth, but at a depth of 25 m. already we find here the same salinity as at 30 m. at St. 170. In the deeper layers we find practically the same values at both stations, but there is a distinct maximum at a depth of 100 meters at St. 175.

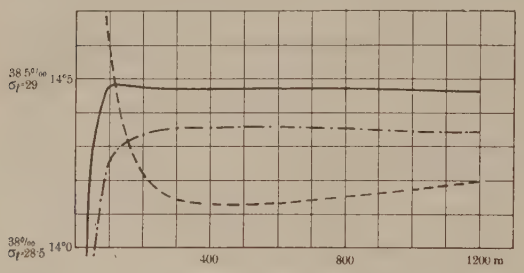

Fig. 2. (St. 170).

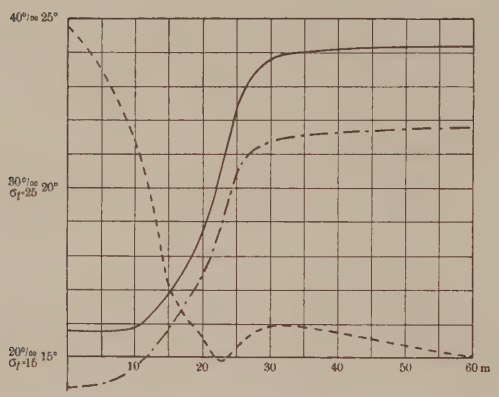

Fig. 2a. (St. 170).

The distribution of the temperature is also very uniform at the two stations; at the surface the temperature is ca. 25° and rapidly decreases downwards, though most rapidly at St. 170. We have a marked minimum at a depth of 22.5 meters at St. 170 (14.95°) and at 20 meters at St. 175 (15.55°), and already at 30 meters we meet with a maximum of respectively 15.9° and 16.6°. From this depth the temperature again decreases; at St. 170 it assumes a minimum value, 14.13°, at ca. 500 meters, rising slowly thereafter towards the bottom, whilst at St. 175 it decreases somewhat more slowly with the depth and seems to be fairly constant below 600 meters. The temperature at the bottom here is 14.07°, which is ca. 0.1° lower than at St. 170.

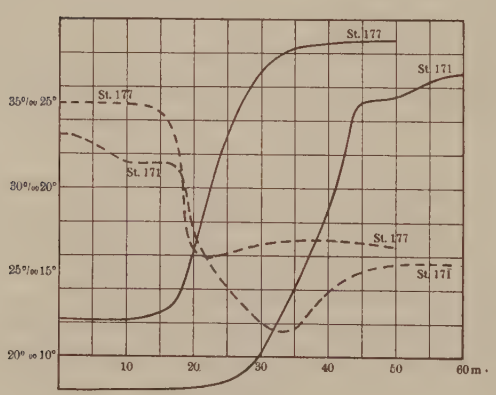

Fig. 3.

St. 177 (fig. 3) at the entrance to the Dardanelles resembles St. 175 in all essentials, but the temperature minimum here is at ca. 25 meters, and the surface salinity is 22.14 ‰; it is worthy of remark, however, that we find here at the bottom (50 meters) the highest value for the salinity in the Sea of Marmora, namely 38.77 ‰.

From these curves and the vertical section fig. 4, from the Black Sea through the Bosphorus and Dardanelles to Euboa, we see that there is a thin surface-layer with great variation in temperature down to ca. 20 meters over the whole of the Sea of Marmora. The salinity is constant down to a little over 10 meters and the variation from east to west is also but slight, ca. 0.5 ‰; from 15 m. the salinity rises about 1 ‰ per meter down to 25—30 meters and in this interval there is likewise a temperature minimum lying between 20 and 25 meters, which is succeeded by a maximum at ca. 30 meters. Whilst the temperature decreases from this depth, the salinity increases until at 50 m. it almost reaches the normal value for the bottom-water; at about 100 meters the salinity shows a slight maximum (fig. 5). The temperature still decreases

slowly down to about 200 meters and in the eastern part of the basin at any rate, where the temperature is a little higher than in the western, it has a minimum at ca. 500 m., after which it again rises a little towards the bottom.

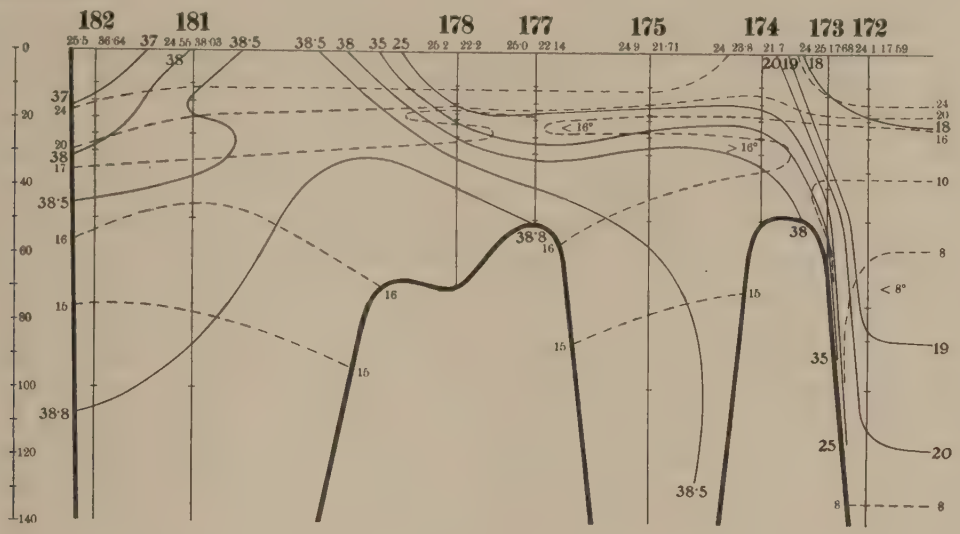

Fig. 4.

Before 1894 only a few, scattered hydrographical observations were to hand from the Sea of Marmora, but in that year a rational investigation was begun, on the one hand by the Austrian expedition with the "Taurus" under the direction of NATTERER, on the other by SPINDLER on the Turkish steamer "Selanik", which was fitted out for the work by the Sultan of Turkey. Unfortunately, the water-bottles used by the "Taurus" have very often been leaky and thus contained almost unmixed surface-water on being hauled up from deep water. NATTERER [1895] did not give this source of error due weight and his conclusions with regard to the circulation in the Sea of Marmora are thus extremely erroneous. The observations of NATTERER which may be considered uninfluenced by these chance errors, give results which agree well with ours for the bottom-layer, namely, a salinity varying round about 38.4 ‰ and a temperature of about 14.2°.

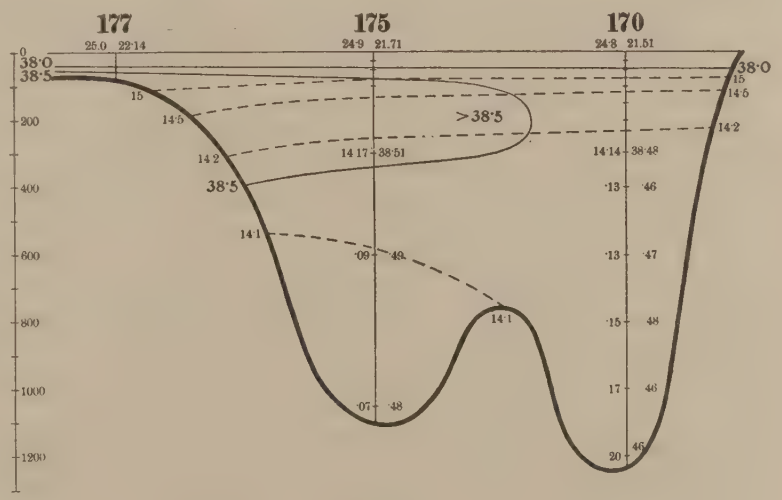

Fig. 5.

SPINDLER [1898, p. 148] distinguishes between 4 different layers:

1. 0—11 m.: homothermal and homohaline surface-layer,
2. 11—25 - : transition-layer with a fall of 2° in temperature and a rise of ca. 10 ‰ in salinity,
3. 25—200 - : temperature ca. 15°, salinity 38.1 ‰,
4. below 200 m.: bottom-layer, homothermal (14.2°) and homohaline (38.4 ‰).

For the first two layers this scheme agrees with our observations; in the uppermost layer we find a fairly great fall in the temperature, but SPINDLER's observations were made in September-October and thus gave a constant temperature in this layer, since a relatively slight cooling of the surface will give rise to vertical currents, which soon spread a uniform temperature near the surface. For the bottom-layer also SPINDLER's results agree well with ours, as the small variation in temperature could scarcely be detected when the thermometer was read only to 1/10th of a degree. On the other hand, there is a very important difference in our results for the layer between 25 and 200 meters; here we have found a maximum for the salinity of ca. 38.5 o/oo (at St. 177 even 38.77 °/oo) about 100 meters, which shows, that the Mediterranean water in almost unmixed condition flows through the Dardanelles into the Sea of Marmora.

I may briefly refer here to the causes of the special hydrographical conditions prevailing in the Black Sea and Sea of Marmora, which are analogous in several respects, and to the water circulation in these basins. The surface-current flows outwards with such rapidity, that mariners of the earliest times must have been well-acquainted with it, and according to MAKAROFF [1899a] it was already known at the end of the 17th century, that an under-current existed in the Bosphorus running from the Sea of Marmora into the Black Sea, as MARSILLI mentions it in a letter to Queen Christina of Sweden. This has later been considered erroneous, however, and it was only in 1872, that WHARTON by means of current-measurements again proved the existence of this under-current [1]. Some years after this, MAKAROFF showed, that the density of the water in the Bosphorus was very variable, being almost twice as great for the bottom water as at the surface, a condition that can only be explained by an inflow of the salt under-layer from the Sea of Marmora into the Black Sea; this inflow was also discovered by MAKAROFF by means of direct current-measurements.

Regarding the cause of these movements, however, there is disagreement between the two observers, as WHARTON [1899] assumes the primary cause to be, that the prevailing north-east winds of the Black Sea press its surface-water towards the Bosphorus through which it finds an outlet. This is a very plausible explanation, so far as the surface-current is concerned, but how an under-current in an opposite direction could arise in this way, is not quite so clear. MAKAROFF [1899b] gives an excellent and satisfactory explanation of this under-current. The large rivers flowing into the Sea of Azov and the Black Sea bring down much larger quantities of fresh water than are lost by evaporation and the excess must be carried away through the Bosphorus; from his observations on the density MAKAROFF finds the averages 1.0140 and 1.0283 for the Black Sea and the Sea of Marmora respectively and then from the laws of communicating tubes he estimates that the level of the former is ca. 43 cm. higher than that of the latter. This difference in level tends to be adjusted by the outflow through the Bosphorus, but in consequence of this, differences arise in the pressure at the same level in the deeper layers, which lead to an inflow of the salt water-masses from the Sea of Marmora. This inflow owing to the high density is obliged to proceed along the bottom through the Bosphorus.

From his current-measurements MAKAROFF calculates the quantities of water which pass through the Bosphorus in opposite directions and comes to the result, that the under-current carries almost as much water into the Black Sea as the amount of freshwater added from the Danube (i. e. ca. 200 cubic kilometers annually) and that the outflow is almost double the inflow. MAKAROFF shows, that the thickness of the outflowing layer in the Bosphorus decreases from ca. 27 fathoms at the entrance from the Black Sea to ca. 11 fathoms at the outlet to the Sea of Marmora. This fresher water, which leaves the Black Sea with a salinity of ca. 17.5—18 °/oo, is somewhat mixed through the Bosphorus with the inflowing salt water, up to 21.5—22 °/oo, and then spreads out as a thin surface-layer over the whole Sea of Marmora. The thickness of this surface-layer varies according to SPINDLER [1895] with the place and is somewhat

[1] From current-measurements SPRATT [1871] came to the result, that there was no under-current running in an opposite direction to the surface-current.

less, for example, in the south-eastern part at Prince Islands than at Gallipoli, but is stated to lie between the limits 12 and 22 meters.

The less saline surface-layer of the Black Sea is due naturally to the rivers flowing into it; on mixing with the upper layers of the Black Sea the fresh water from these rivers forms a surface-layer which, as mentioned, has a salinity of 17.5—18 ‰ (somewhat less in the neighbourhood of the coasts and the rivers), whilst the higher salinity of the bottom-layer arises from a mixing with the salt water-masses from the Sea of Marmora, the mixing process taking place, as appears from the salinity 36.5 ‰ at the bottom at St. 173, chiefly in the Black Sea itself and not in the Bosphorus (SPINDLER also found a very high salinity, 33.8 ‰, at the bottom (72 m.) at his station 54). SPINDLER [1898, p. 149] has made a very meritorious calculation of the amount of evaporation from the surface of the Black Sea and of the total quantity of fresh water which flows into this basin; his result is, that the increment of fresh water exceeds the evaporation by ca. 460 cubic kilometers, which, spread over the whole Black Sea, corresponds to a rise of level of 121 cm. (after a later calculation of the area of the Black Sea ca. 101 cm.). Further, SPINDLER calculates the average rate of flow of the current which can carry this mass of water out through the Bosphorus in the course of the year, assuming the thickness of the current to be 20 meters, and he finds a rate of 73 cm. per second, which agrees quite well with MAKAROFF's observations.

There is reason to remark, however, that the outflowing volume of water must be almost twice as great as the excess of fresh water—presupposing that the total quantity of salt in the Black Sea remains to some extent constant. As this fresh water does not flow out as such, but as a mixed product with a salinity of ca. 18 ‰, the relation will be approximately, that every unit of volume of fresh water flowing outwards takes up a unit of the incoming Mediterranean water and that the quantity of salt lost is replaced by the inflow of a unit of volume of the salt Mediterranean water, that is to say, almost as much water flows in through the Bosphorus as the total quantity of fresh water added to the Black Sea, and twice the quantity is flowing out.

The surface-layer of the Black Sea is cooled down in winter to a temperature, which varies naturally from one year to another but is given as 6° C. generally, though this is too high for the northern part. Owing to this cooling the density of the surface-layer increases (at 6° C. it is 1.0142 for a salinity of 18 ‰), but this density is nevertheless considerably lower than that of the bottom-layer, from which it follows, that the vertical currents arising from the cooling of the surface are not able to penetrate down to the bottom-layer and only reach to a depth of ca. 50 meters, as appears from the distribution of densities at St. 172, where the density at the depth mentioned is 1.01422. Even if the surface-water were cooled down to its freezing-point, ca. — 1°, its density would be ca. 1.0146, so that the vertical currents would not be able to reach deeper than about 75 meters. As the salinity rises somewhat from the surface downwards, there is reason to expect, that the salinity of the surface-water will be somewhat higher in winter than in summer, for the whole of the upper layer gets mixed through these vertical currents and thus assumes the same temperature and salinity down to the depth where this movement ceases (this increase in salinity is possibly compensated by a greater addition of fresh water from rainfall and rivers).

So far as I know, the depth to which these vertical currents reach in the course of the winter, has not been determined by direct observations, but it must be approximately the same as the depth at which we meet with the intermediate minimum for the temperature. For in summer, when the water is warmed from the surface, the equilibrium of the surface-layer will be stable and the lowermost part of the layer cooled down in winter will remain almost unchanged, until the heat from the surface reaches it, though the temperature minimum may perhaps sink down slowly in the course of the summer, as seems to be indicated by SPINDLER's observations.

In consequence of the fact, that the vertical currents are confined in the winter-time to a relatively thin layer of water, which shuts off the extensive bottom-layer from direct connection with the

atmosphere, compensation for the quantity of oxygen used up by reducing processes is only brought to the bottom-layer by diffusion through the uppermost layer which proceeds slowly and by the inflowing water from the Sea of Marmora. The oxygen brought by these two ways is not sufficient in amount to replace what is used up by the reducing processes in deep water. These reducing processes are here very considerable, partly as a result of the rich animal-life in the uppermost layer, the dead individuals sinking down and becoming decomposed in the bottom-water, partly as a result of the large quantities of organic materials, which are brought down by the rivers and likewise sink down into the deeper layers, where decomposition goes on. During these reduction processes not only is the absorbed oxygen in the seawater used up, but an excess of hydrogen sulphide arises, either from a reduction of the sulphates present in the seawater, as NATTERER supposes [1895, p. 20], or from the decomposition of the organic matter. Regarding the movement in deep water, we must assume the presence of horizontal currents, as the salinity otherwise would be greatest in the south-western part in the neighbourhood of the Bosphorus, which is not the case according to SPINDLER'S observations.

With regard to the inflow and outflow to and from the Sea of Marmora, the conditions are quite analogous to those for the Black Sea, except that the Dardanelles here have the same part to play as the Bosphorus for the Black Sea, whilst the latter takes the place of the rivers. As we have seen, the salinity of the Mediterranean water flowing in through the Dardanelles is very high (up to 38.8 ‰), and when its temperature is below 15° C., it has a higher density than the bottom-water in the Sea of Marmora. There is no doubt, however, that the temperature of the inflowing Mediterranean water is in winter considerably lower than 15° (possibly about 13°), and this water will thus sink down to the greatest depths of the Sea of Marmora whilst mixing partially with the water-masses already there; in summer, on the other hand, it will remain as an intermediate layer with a maximum salinity owing to the lower density consequent upon the high temperature.

As already mentioned, the temperature in deep water is somewhat lower in the western part of the Sea of Marmora than in the eastern part. The explanation of this phenomenon is, that there is a slight ridge across the middle of the basin from north to south, with depths somewhat less than to the east and west; consequently, the influence of the inflow of water in winter is most pronounced to the west of this barrier. As further, striking evidence of the correctness of this conclusion, I may mention that, whilst the relative amount of oxygen at the most easterly station 170 increases from 27.3 to 36.8% at depths from 300 to 1200 meters, the values at the more westerly station 175 are respectively 31.9 and 42.1%. Further, in addition to an appreciable difference in the values for the temperature in the bottom-layer at the two stations, there is also some difference in the course of the temperature curves, that for St. 170 recalling more the conditions in the true Mediterranean, as I shall show more closely on discussing the temperature in the deep water of the Mediterranean.

Although the bottom-water of the Sea of Marmora is shut off from ventilation from the surface to an even greater extent than the bottom-water of the Black Sea, the difference in the densities being here much greater (for the bottom-water the density is ca. 1.0288, for the surface-water even when cooled to 0° about 1.0178), hydrogen sulphide has not been detected here by the earlier expeditions. It will be seen also from the stations 170 and 175, that the lowest value observed for the relative amount of oxygen is ca. 27%. This percentage is certainly low, but compared with the Black Sea, which is indeed somewhat more favourably situated as regards the possibility of ventilation from the surface, the difference is striking. The reason is, that the bottom-water of the Sea of Marmora is renewed comparatively rapidly, a portion flowing in through the Bosphorus, whilst another, though smaller portion returns out with the surface-current through the Dardanelles and is replaced by new water-masses from the Aegean Sea. In the winter-time this renewal will be felt down to the greatest depths in the basin. The reason why the conditions for the ventilation of the bottom-water are so favourable for the Sea of Marmora is then, that the

total capacity of this is small by comparison with that of the Black Sea, so that a relatively large part of the total mass of water is removed and can be replaced by new masses of water rich in oxygen from the Aegean Sea.

As already mentioned, SPINDLER found that the thickness of the fresh surface-layer in the Sea of Marmora varied with the locality, as seems very natural; nevertheless, there is no little disagreement in the estimates of the different observers for the volume of this current at the same places in the Bosphorus and Dardanelles. At Chanak in the latter MAGNAGHI even found, that it was only about 10 meters thick. This need not seem remarkable, however, the causes which produce this current are so variable in the course of the year, that we may well expect, that both the rate of the current and its volume are subject to very rapid and great changes. As it was possible also, that there might be a daily periodicity in the volume of the current, such as Dr. SCHMIDT [1911, p. 63, also KNUDSEN 1911] had found in the Færoe-Shetland Channel in the spring of 1910, a continuous series of observations were made in the Dardanelles off Chanak.

The "Thor" was anchored in about 60 meters of water and temperature and areometric observations were made with the object of determining the boundary between the fresh, outflowing surface-layer and the salt, inflowing bottom-water. To reduce the influence of the current on the water-bottle, this was weighted with a lead of 5 kg. more than usual, and to be able to make the determinations rapidly in succession, an ordinary, unprotected surface-thermometer, which owing to its great sensitiveness allowed the readings to be made as quickly as the water-bottle could be hauled up, was placed in the latter. The readings are naturally not so very accurate, but the differences to be determined amounted to several degrees, as will be seen from the following table. The observations were made on August 12th, from 5 to 11 p. m.

We see from the table, that the transition from the surface-layer, in which the temperature is 24° and the salinity ca. 23 ‰, to the bottom-layer is very sharp as a rule; thus, at 5.24 p. m. the temperature decreases over 6° from 16 to 18 meters, and if we place the boundary between the two different layers at 20°, it will thus lie at a little below 17 m. At 6.35 p. m. there is a fall of temperature of over 5°

	Depth	Temp.	Sal.		Depth	Temp.	Sal.
5.10 p. m.	15	23.6	23.8	7.26 p. m.	14	21.15	27.8
14	20	17.8	37.8	30	13	23.7	23.6
17	25	17.4	38.6	34	5	24.9	—
21	16	24.4	22.9	35	0	24.9	22.5
24	17	21.2	29.1	8.55	15	24.1	22.9
28	18	18.25	33.6	9.00	16	24.05	22.9
33	19	17.7	35.0	03	17	24.0	22.9
38	15	24.4	23.0	06	18	24.0	23.5
42	14	24.4	22.9	09	19	23.1	24.5
46	13	24.45	22.8	12	20	17.95	36.5
49	12	24.65	22.6	15	21	18.05	36.5
53	11	24.75	22.5	18	22	17.8	36.9
57	10	24.8	22.5	22	25	17.25	38.3
6.00	5	25.0	—	28	20	20.2	28.9
00	0	25.0	22.4	10.02	20	23.6	25.2
35	15	24.25	23.0	05	21	18.05	35.0
40	16	18.85	31.0	09	10	24.5	22.4
44	17	18.75	32.2	12	0	24.75	22.3
48	18	17.8	35.3	10.45	21	17.55	37.1
53	19	17.6	36.0	48	18	18.7	31.2
58	20	17.6	36.7	52	17	20.4	26.8
7.02	22	17.4	38.2	56	16	20.9	26.2
07	25	17.3	38.4	11.00	15	20.7	26.6
13	60	16.5	38.7	03	13	24.1	22.9
18	10	23.9	23.0	06	14	23.25	22.6
22	15	19.1	29.9				

between 15 and 16 m., at 7.22 p. m. the boundary lies a little higher, between 14 and 15 m.; at 9.09 p. m. it is between 19 and 20 m. and moves a little deeper until 10.05 p. m., when it lies between 20 and 21 m., but in the course of an hour it goes up over 3 m. and we notice that the temperature and salinity have almost the same values at 17—15 m. from 10.52 to 11 p. m. To consider this as evidence of the presence of a uniform layer of water during this interval, would probably be erroneous; all the earlier observations show a great and sudden change, and the uniform values here are probably due to the boundary moving about 1 m. upwards in the 4 minutes between two successive observations and the 3 observations in question have thus been made at depths lying at the same relative distance from the boundary. We see, in fact, that the observation at 16 m. gives a somewhat higher temperature and lower salinity than that at 15 m., which would indicate, that the water, which at 10.56 was at 16 m., was scarcely 15 m. under the surface at 11 p. m.

If we mark down the observations on a coordinate system, with the time as abscissae and as ordinates the depths in which the boundary of the freshwater current occurs at the time indicated, we obtain a curve whose course does not indicate, that these fluctuations can be dependent on tidal currents. In this connection I may mention, that the surface-current varied considerably in strength in the course of quite a short time, and that it showed a strong tendency to form local whirlpools quite irregularly at different places. On the whole, this current seemed to be considerably more complicated than was imagined earlier, and it will probably be an interesting study for observers who can devote a longer time to this question.

IV. The Aegean Sea.

Our observations in the Aegean Sea are too few naturally to give a complete picture of the hydrographical conditions there. From the investigations of the "Pola" in 1893 [Luksch and Wolf 1894] it appears, that the salinity and especially the temperature are very variable from one place to another, even in the deeper layers; this is due to the complicated system of depths, the deeper parts of the Aegean Sea consisting in reality of several, sharply defined basins. Thus, there is a deep basin in the north (at the northern Sporades), where the temperature at great depths is under 13°, whilst our stations 163, 181 and 182 all lie in the central part bounded to the south by the series of islands Euboa-Andros-Timos-Nicaria-Samos.

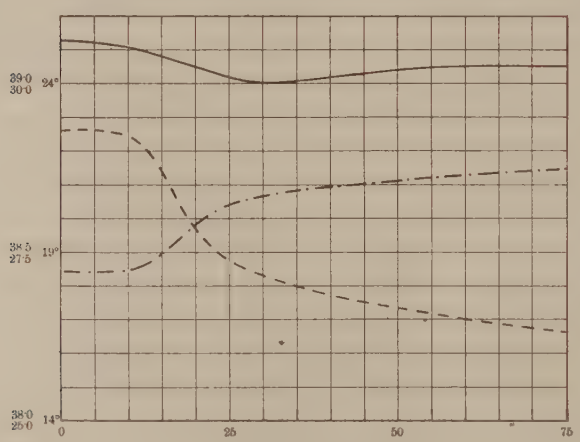

Fig. 6a. (St. 163).

These stations show various remarkable conditions, however, as will be seen from the curves figs. 6 and 7. In the neighbourhood of the surface both the temperature and the salinity are very different and, curiously enough, the surface temperature at station 163 lying north of Nicaria (figs. 6 and 6a) is almost 3° lower than at St. 182 (fig. 7) in the neighbourhood of Euboa. The surface temperature is on the whole very variable in the Aegean Sea, but as a general rule we can hardly say, that the temperature on the east side is lower than on the west, as the

opposite is rather the case. Thus, whilst the temperature at the surface at St. 163 north of Nicaria was only 22.60°, it was 26.0° a little to the south of the island, and the value 22.60° is quite the lowest found in the Aegean Sea.

This condition was probably due to purely local causes, and we notice also, that the layer nearest the surface, in which the temperature is almost constant, has much less thickness at St. 163 than at St. 182. At St. 182, however, the temperature decreases very greatly — about 7° — from 20 to 30 m., whereas it decreases slowly at St. 163 and at 30 meters already we find a higher temperature than at St. 182, a condition that becomes even more distinct in greater depths, as will be seen from the following results:

Depth	0	10	25	30	50	75	100	200	300	400 m.
St. 163	22.60°	22.45°	18.75°	ca. 18.3°	17.36°	16.60°	16.28°	15.26°	14.31°	13.53°
St. 182	25.5°	25.5°	22.05°	18.0°	16.25°	15.0°	14.72°	14.32°	14.04°	13.72°

Whilst the temperature at St. 182 decreases fairly steeply right to the bottom, at St. 163 it has a minimum at a depth of about 700 meters, where the value is 13.34°; from there it again rises slowly towards the bottom just as in the Sea of Marmora, but at the greatest depth it is here 0.7—0.8° lower than in the latter.

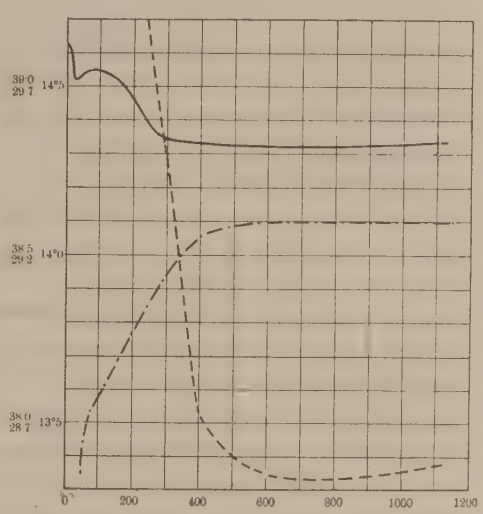

Fig. 6. (St. 163).

It will be seen from the curves, figs. 6 and 7, that the salinity is very different at the two stations. In the neighbourhood of Euboa the surface salinity is only 36.64 ‰, deeper down the salinity increases greatly and is 38 ‰ at ca. 28 m., but down to 250 meters it remains lower than in the same depths at St. 163; below this depth we find almost the same value, though the vertical distribution is a little different, being constant from 300 m. to the bottom at St. 163 whilst there is a maximum (38.86 ‰) at St. 182 at a depth of 300 meters. The low salinity in the neighbourhood of the Grecian coast arises naturally from the fresh surface-water flowing out from the Dardanelles, which owing to the earth's rotation is inclined over towards the western side of the basin. Out from the Grecian coast the salinity increases greatly and at St. 181 is over 38 ‰ at the surface (see fig. 4); a surface-sample taken at St. 180 even has a salinity of 38.64 ‰ and is thus but little influenced by the fresh water from the Sea of Marmora.

At St. 163 there is very little variation of the salinity with the depth, the lowest value observed being 38.82 ‰ and the highest 39.13 ‰. The curve of fig. 6 shows, that the salinity has a maximum at the surface and decreases 0.1 ‰ to 25 m.; from 25 to 150 m. it is almost quite constant and from there decreases about 0.2 ‰ down to 300 m., remaining constant thereafter at 38.83 ‰ right to the bottom. So far as the bottom water is concerned, the latter value is higher than at any other place in the Mediterranean at the same depth.

St. 183 in the innermost part of the Gulf of Aegina near the Corinth Canal differs greatly from the stations east of Euboa (compare St. 182 in fig. 7). The temperature and salinity are respectively 12.61° and 38.51 ‰ at the bottom (225 m.), thus about 1.6° and 0.35 ‰ lower than the values found at the same depth at St. 182. During the winter cruise of 1908, on December 30th, a station (No. 18) was taken at very nearly the same place; 12.78° and 38.57 ‰ were then found at the bottom at a depth of 200 m., thus slightly higher values than in August 1910. The salinity in the surface-layer was also higher in the winter and the temperature, salinity and consequently the density were constant from the sur-

face down to about 75 m., showing that the vertical currents from the surface, owing to the cooling process, have reached down to this depth and will probably as a rule continue down to the bottom in the course of the winter.

We see, therefore, that the innermost, deeper part of the Gulf of Aegina is also an independent region in hydrographical regards, the hydrographical factors being in part independent of the Aegean Sea; the temperature at the bottom is the minimum value to which the whole body of water is cooled in winter and the salinity arises from a mixing of the whole caused by the convection currents of the cooling process. That the salinity of the bottom-water is lower here than in the Aegean Sea, finds a natural explanation in the fact, that the salter layer of water below is of less extent, so that the fresher surface-layer coming down from the Black Sea has a greater relative influence in reducing the salinity; similarly, the relatively low bottom-temperature has its origin in the fact, that a definite loss of heat from the surface causes a reduction in the temperature, which is inversely proportional to the depth.

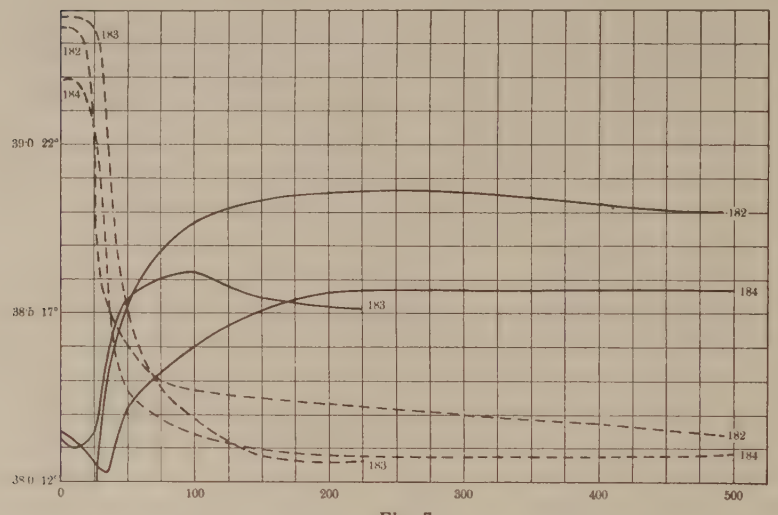

Fig. 7.

As the uppermost part of this homohaline layer must be considered to flow away gradually and be replaced by a less saline surface-layer, the salinity of the bottom-water would decrease in the course of years if an inflow of salter water did not take place. The intermediate maximum in the salinity at St. 183 shows, however, that such an inflow occurs in the course of the summer; but it does not penetrate to the bottom-layer, as the comparatively shallow depth at the mouth of the Gulf does not permit this, and it has its greatest intensity at a depth of 100 meters, which is approximately the maximum depth on the threshold between Salamis, Aegina and Methana.

As the salinity at St. 163 in the eastern part of the Aegean Sea has its maximum at the surface, which is not separated from the bottom-layer by any intermediate minimum, we see, that the cooling of the surface-water to 1° above the temperature of the bottom-water, thus at 14.4°, will give it a density which is greater than that of the bottom-water and a continued cooling will thus give rise to vertical currents down to the greatest depths. As the air-temperature over the Aegean Sea is relatively low in winter (the mean temperature for January at Athens is 8.0° according to Hann [1908a, p. 216], 8.65° accoring to Éginitis [1896, p. 54]), there is reason to expect that — except perhaps in a few very mild winters — the surface-water will be regularly cooled down so much that it can sink to the greatest depths; this means that the whole body of water becomes mixed and ventilated.

That these vertical movements have taken place in the preceding winter, is undoubtedly the reason why the layer of water from ca. 400 m. to the bottom has a constant temperature, salinity and density and is consequently in a condition of indifferent equilibrium. As a second, clear indication of the vertical movements in the Aegean Sea I may mention, that the relative amount of oxygen is here over 88 % even at the greatest depths, a percentage which is considerably higher than at any other place in the Mediterranean with exception perhaps of the Adriatic Sea.

V. Eastern basin of the Mediterranean.

I. Remarks on the diurnal range of temperature in the surface-layer.

The principal factor in the hydrography of the eastern basin — and through this of the whole Mediterranean — is the evaporation from its surface. In the course of the very warm and quite rainless summer enormous volumes of water are evaporated from the surface of the sea which at the same time assumes a high temperature. This evaporation leads to an increase in the salinity of the surface-water and if the heating process was quite continuous the salinity would reach a very high value, before the surface-water owing to the increasing density sinks down through the layers below, as the rise in temperature of the surface-water will to a certain extent counterbalance the increase in the salinity and maintain the density at nearly the same level.

The heating of the surface-layer is however not continuous; on the one hand, the air-temperature varies and not rarely becomes lower than the temperature of the surface-water within a short time and during the night, again, the air will frequently have a lower temperature than the surface. In such cases the water will give off heat partly by conduction to the air, partly by radiation and evaporation, leading to an increase of density in the uppermost layer and when this density becomes the same as in the layer immediately underneath, further cooling will cause the surface-water to sink down until the temperature, salinity and density are constant in the column of water, in which the vertical movement is taking place. The lower boundary for the vertical circulation will be determined by a layer of water with higher density (whether from a lower temperature or a higher salinity) than that which is present in the product of the mixing process at the surface.

To illustrate these conditions still further I may give the following example; let us assume that the temperature and salinity at the surface are respectively 25° and 39.20 ‰, decreasing proportionately with the depth to 23° and 39.00 ‰ at a depth of 10 meters; σ_t is then 26.53 at the surface, 26.76 at a depth of 5 and 26.98 at 10 m. As soon as the temperature of the air sinks below 25° at night-time (in reality a little earlier, as heat is absorbed during evaporation), the uppermost layer becomes cooled, let us say, to 24.8°; its density will then be 0.000016 higher than the density at a depth of 1 m., where the temperature is likewise 24.8°, from which it follows, that the water-particles at the surface sink down and are replaced by others, thus causing a mixing of the particles in the layer of ca. 1 m. in thickness, so that the temperature and salinity become uniform at respectively 24.8° and 39.19 ‰. If the cooling process continues, the vertical movements are continued downwards, and at the moment when it reaches to a depth of 10 meters, the product of the mixing above will have a salinity of 39.10 ‰, and as the density of this must have the same value as that previously existing at 10 m., namely 26.98, it follows that this layer of water must have a temperature of 23.28°.

We see, therefore, that the vertical movement produced by the cooling of the surface, from which arises the constant temperature and salinity in a layer of greater or less thickness according to the intensity of the cooling, leads to a rise both of the temperature and salinity in the lowermost part of the layer which takes part in the movement, when as in the example cited both the salinity and temperature originally decreased from the surface downwards. In the example cited the increase at a depth of 10 m. is 0.28° and 0.10 ‰, at 9 m. 0.08° and 0.08 ‰, whilst the temperature at a depth of 8.6 m. is unchanged, but the salinity increased by ca. 0.07 ‰. If we imagine the surface-layer again warmed up until the temperature and salinity gradient again has the original value and then cooled again to the same temperature as above, 23.28°, a new quantity of salt is again brought down by this process and the temperature rises from 10 m. to about 12 m. It follows from this, that when the temperature and salinity decrease from the surface downwards, a cooling of the surface will always produce a rise in both in the lowermost

part of the layer, which takes part in the vertical movement caused by the cooling; it is further evident, that the depth at which this warming process goes on, increases with the number of successive heatings and coolings of the surface.

This transport of heat downwards will not be produced by successive heating and cooling of freshwater or of seawater in which the loss of fresh water on evaporation is compensated for by rainfall or other source of freshwater, as the heat transport is dependent on an increase in the salinity of the surface-water during the heating process. That the heat carried down in this way is by no means inconsiderable, is seen from the example cited, where the layer of water between 8.6 and 10 m. receives an amount of heat which is about $0.9 \times 0.14 \times 140$ or ca. 18 cal. per cm.^{2} of surface. We see further from this example, that a strong heating in the course of the day, even if it goes on daily for a long period, will not produce any great rise in the surface-temperature, unless the air-temperature at night is also higher than that of the surface-water. If this is not the case, the greater part of the heat received during the day will be given off at night to the atmosphere, whilst a part (in the above example $\frac{0.14 \times 1.4}{0.86 \times 8.6} = \text{ca.} \frac{1}{38}$) will be carried down by convection currents. In the neighbourhood of the surface we should then have a layer of water with almost uniform temperature and salinity, the volume or extent of which will vary with the duration of a warm period.

Regarding the depth to which the daily fluctuation of temperature reaches, we have no direct observations; this problem must naturally be solved by continuous measurements over a long period at one and the same place. But even these measurements will only give a very uncertain result, as it is evident, that when horizontal movements take place in the uppermost layer of water the measurements will not be made in the same column of water, which is a necessary presupposition for the satisfactory solution of the problem, and we can readily see, for example, that an inflow of colder water-masses in the course of the night will give too high a value for the daily variation of temperature.

The depth generally given for this variation is probably too great. In order that an appreciable cooling should take place at, for example, a depth of 15 meters in the course of the night, we can see from the above example, that the whole layer of water from 0 to 15 m. must be cooled down to a temperature which is lower than that at 15 m. If this does not take place, the only way by which a fall of temperature at 15 m. is possible, will come from a loss of heat by conduction to the deeper, colder masses of water, but if the temperature in the layer immediately above has not decreased in consequence of cooling from the surface, the loss of heat arising in this way at a depth of 15 meters will be replaced by a conduction of heat from above.

If we consider, for example, the temperature curve of fig. 8a, p. 125, the effect of a cooling in the night will be, that the first part of the curve will become horizontal and that a cooling to 24° will give a uniform temperature down to about 20 meters, but such a cooling will in no way affect the temperature 21.7° at 25 m., as the loss of heat by conduction downwards will be counterbalanced from above, the part of the curve lying immediately above 25 m. being still unaffected by the cooling. It is only when the surface becomes further cooled, that the effect will gradually reach deeper down — as the salinity is greatest at the surface, a rise of temperature at 25 m. will even occur at a certain stage, by analogy with the above-cited example — and only when the surface has cooled down below 21.7° will there be any effective cooling at a depth of 25 meters.

As no very great variations occur in the surface-temperature in the course of the 24 hours — as a rule scarcely more than one degree — it seems to me evident from the above explanation, that the daily fluctuation of the temperature must be confined approximately to the layer of water close to the surface, in which the temperature varies comparatively slowly with the depth (e. g. in fig. 8a to ca. 15 m.); where the temperature below this decreases rapidly with the depth, the daily variation of the temperature

will only be able in exceptional cases to extend more than some few meters below the boundary for the surface-layer, in which the temperature only varies comparatively little. As will be shown in the sequel on discussing the different temperature curves, the thickness of this layer of water at the times when our summer investigations were made, was much less than the statements usually made with regard to the depth for the daily variation of the temperature, and there is scarcely any reason to doubt, therefore, that on renewed investigation these statements will be found to be far too high, at least for the summer months [cf. KNOTT 1906].

In the above-mentioned instance the amount of heat received at a depth of 25 m. through radiation is thus very small in comparison with the heat absorbed by the uppermost meter of water; further, no cooling can take place at this depth during the night. Consequently, there can only be a very small heating during the day but no daily variation, i. e. no periodic heating and subsequent cooling in the course of a day and night.

A presupposition underlying what has been said above as to the daily variation of temperature in the surface layer is, naturally, that there are no other movements than those arising from the disturbance of equilibrium caused by cooling of the surface. This supposition naturally is not fully realized; rough weather and horizontal currents over an uneven bottom and along a coast with projecting promontories give rise to circular movements, which lead to various mixing processes, which again influence the temperature. We may leave these mixing processes out of consideration, however, in dealing with the diurnal variation of temperature, in so far as they only cause some unperiodic disturbance in the daily, periodic heating and cooling.

2. The distribution of temperature and salinity.

We may now consider more closely the results of our observations made about the 1st of August 1910 in the Levant. The stations 156—160 lie in a line from Rhodes to a little east of Solum Bay and the results of the observations for the two outermost stations are shown graphically in figs. 8 and 9, whilst Sect. 1, Pl. III, represents a vertical section from Rhodes to the coast of Egypt. Figs. 8a and 9a show, contrary to what we should expect, that the temperature at the surface is ca. 0.8° higher on the northernmost station than at the southernmost but it decreases more rapidly at the former and has the same value already at about 20 meters. At 25 meters the temperature is almost 1° higher at St. 156 than at St. 160 and, excluding the depths about 50 meters where the value is almost the same at both stations, we see (figs. 8 and 9), that the temperature remains somewhat higher at the southernmost station down to about 1500 meters, but between 1000 and 3000 meters the difference between them is only some few hundredths of a degree.

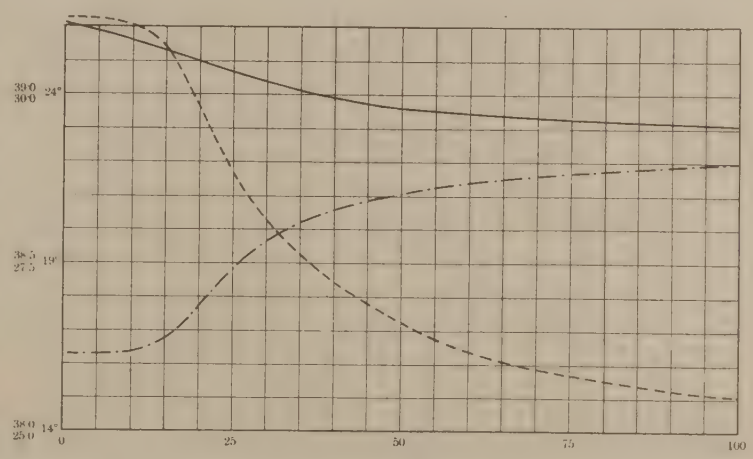

Fig. 8a. (St. 160).

Greatest interest is attached, however, to the course of the two temperature curves in deep water. We see that these, in contrast to what has been believed hitherto, do not remain horizontal, but that the

temperature decreases down to between 1000 and 1500 meters. Nor is the temperature constant even from this depth; we find here a minimum very near to 13.6° and then an increase downwards, an increase which is more or less proportional to the depth and amounts to 0.19° at St. 160, where the bottom-temp-

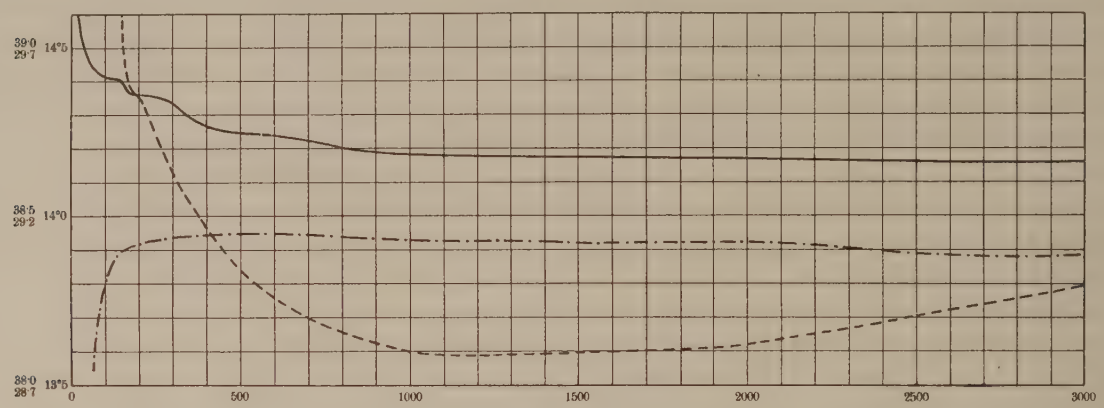

Fig. 8. (St. 160).

erature is 13.78°; at St. 156 the increase in the temperature from 1500 to 3000 meters is somewhat less, namely 0.15°, but the lowest reading was taken at some distance from the bottom, so that the rise of temperature from the minimum value to the bottom is probably very near to 0.2° here also.

From the curves for the vertical distribution of the salinity we see, that this is almost quite constant at 38.66 ‰ below 800—1000 m. and has the same value at the two stations, whilst from this depth upwards it increases and most strongly at St. 156. At a depth of 160 m. it again has the same value 38.90 ‰ at both stations, but whilst the salinity at St. 160 increases continually towards the surface, where it is 39.22 ‰, it decreases greatly at St. 156 up to 50 m. where it is only 38.48 ‰, but from there again increases rapidly to a little over 39 ‰ at the surface. Excluding the surface-layer down to ca. 20 m., σ_t which is determined only by the salinity and temperature, is lower at St. 156 down to about 400 meters; from this depth it has almost quite the same value at both stations. The curves show also, that it is very nearly constant from 300 to 1500 m., after which it decreases slightly owing to the increasing temperature. At both stations the density is constant from the surface down to about 15 m., but in consequence of the decreasing salinity at St. 156 it increases more slowly here with the depth than at St. 160.

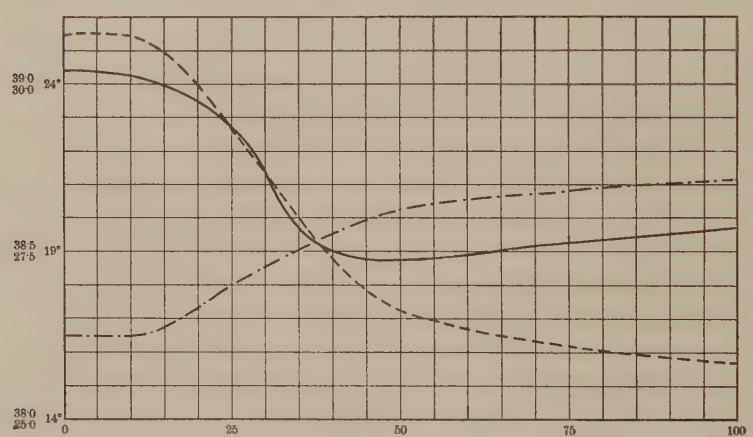

Fig. 9a. (St. 156).

The importance of the peculiar distribution of salinity at St. 156 can be judged most easily from a consideration of the sections 1 and 1 A, Pl. III, which run from the north coast of Egypt to Rhodes. We see, that water-masses with relatively low salinity (below 38.5 ‰) occur under the surface in the southern part of the section off the coast of Africa, from which they extend northwards as a wedge. The lowest value for the salinity is found at a depth of 50 meters, but at St. 156 the fresher water is noticable

down to ca. 150 meters, as can be seen from the course of the 38.9 isohaline. At the surface the value for the salinity is also lower at St. 156 than further north, as is shown by the 39.0 isohaline in the neighbourhood of the surface in section 1 A, and the slope of the temperature curves towards the south indicates, that the warmest water lies on the south side of the section.

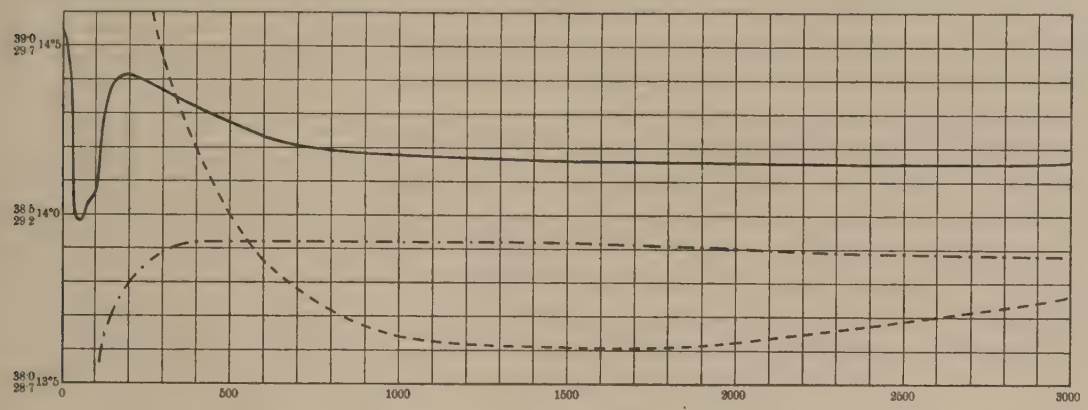

Fig 9. (St. 156).

We shall have frequent occasion to notice later, that there is a layer of water further to the west along the coast of Africa, which is analogous with what we find here in the southern part of the section. There can be no doubt, therefore, that we still find here, so far east as the coast of Egypt, a continuation of the surface-current, which flows in from the Atlantic through the Straits of Gibraltar. If we only had observations of the surface-water, these would not show with certainty this Atlantic water, for the salinity at the surface at the three stations from south to north is respectively 39.04, 39.18 and 39.22 ‰, and even though the southernmost value is slightly lower than the others, yet the difference is fairly small. At 50 m., on the other hand, we have 38.48, 38.96 and 38.96 ‰. That the difference in the surface-salinity is so slight, does not seem remarkable when we remember, that this inflowing water is subjected to the influence of the warm and dry atmosphere during its movement along the coast of Africa, whilst the compensation received from rivers is very small until it reaches the mouth of the Nile. It is also seen from section 1 A, that the increase in salinity is due to a much greater extent to evaporation than to mixing with the salter Mediterranean water; on considering the isohalines in the southern part of the section, for example, we notice that they lie very close to one another above the minimum salinity at a depth of ca. 50 meters (the gradient of the salinity is here over 0.01 ‰ per meter), whereas below this depth they lie comparatively far from one another. If the salinity were mainly increased by mixing, we should expect that this would proceed just as strongly at least on the lower side of the fresher layer of water.

Section 2 A, which runs from St. 156 westwards along the coast of Barka to Sidra Bay, shows, that the intermediate layer of low salinity increases in extent towards the west and that the numerical value of the minimum decreases. Whilst the minimum value of the salinity at St. 156 is only a little below 38.5 ‰, it decreases to 28.2 ‰ at St. 145; but a similar decrease is also found however at the surface, the salinity at the eastern station (156) being 39.04 but 38.51 ‰ at St. 145. The intermediate, fresher layer of water seems to lie somewhat deeper at St. 154 than at St. 156, and we may notice, that both at St. 152 (fig. 10a) and St. 154 there is a surface-layer of over 25 meters in thickness, where the temperature and salinity are uniform, but the temperature in this layer is somewhat lower than in the western and eastern parts of the section; on the whole, also, the surface-temperature on the north coast of Barka is somewhat lower than in the open sea.

These observations were taken very near the coast, however, so that we should be prepared for variable conditions; it is thus easily understood, why the intermediate layer decreases so greatly at St. 156, as this station lies at a considerable distance from the coast, along which these water-masses are in movement towards the east. It is probable, further, that the prevailing north-west winds over the Ionian Sea and Levant, which are almost like trade-winds in constancy, (see Rung [1904], Seewarte [1905]), produce a welling-up of surface-water with relatively high salinity along the coast of North Africa, but this does not explain the somewhat lower temperature in this layer. It is possible, that the lower temperature is due to a cooling of the surface at this period — the air temperature was at that time (26—29 July) somewhat lower than that of the surface-water, fluctuating about 24° — with subsequent sinking down and mixing of the uppermost layer of water, as we have already described in detail; or it may be, that a purely mechanical mixing of the surface-layer has taken place during its movement along the coast under the influence of tidal currents and winds, a mixing process that often occurs in the neighbourhood of a coast, leading to a reduction in the temperature of the surface-water in consequence of its mixing with the colder masses of water below the surface.

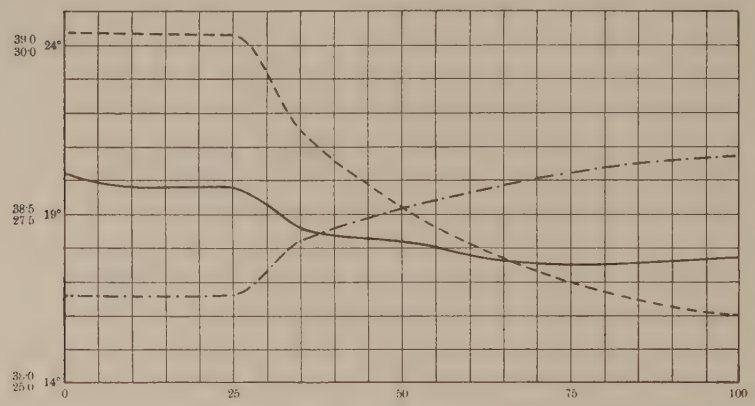

Fig. 10a. (St. 152).

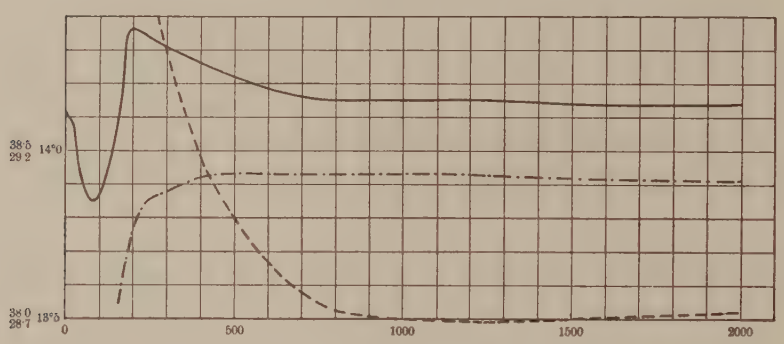

Fig. 10. (St. 152).

The section 2 A extends from the Levant into the Ionian Sea; between these there is no sharp boundary, this being simply a line from the south point of Greece over the west point of Crete to Barka. Nor is there any sharp distinction in deep water, such as for example between the eastern and western basins of the Mediterranean, though an indication of a boundary is present in the form of a submarine plateau running between Crete and Barka, over which the depth is somewhat less than in the Levant and Ionian basins; the maximum depth over this plateau, however, is probably not less than 2000 meters. There is thus no reason to expect any very great difference in the deepest layers, at any rate not at depths less than 2000 meters, and a comparison of the curves showing the vertical distribution of the temperature and salinity at the stations 152, 144 and 187 in the Ionian Sea with the corresponding curves for the stations 160 and 156 in the Levant, shows also that they have in the main the same course except as regards the surface-layer down to about 200 meters. We must always remember, however, that great differences are nowhere to be found in the deep water of the Mediterranean and consequently, that a tenth of a degree has about the same importance in indicating changes as a whole degree in the Atlantic.

A closer comparison [1] of St. 144 (fig. 11) with St. 160 (fig. 8) shows that the temperature below 2500 meters is over 0.1° lower at St. 144, whilst the curves above 2500 m. gradually come nearer to one another; at 1500 m., where the temperature at St. 144 has a minimum 13.55° (at St. 160 the minimum lies somewhat higher, about 1200 m.), the difference of temperature is still 0.05°, but between 700 and 300 m. the two curves are precisely the same. The salinity seems to be almost the same in the deep water of the Levant and Ionian Sea; at a depth of 400 m. we find quite the same value at the two stations, but above this there is an obvious difference. Whilst the salinity at St. 160 rises right to the surface, at St. 144 we find a maximum of 38.80 ‰ at ca. 250 m., from which there is a great decrease to a minimum of 38.13 ‰ at 25 m.; then it rises rapidly again to 38.49 ‰ at 10 m. and continues constant to the surface. From the curve for the density we see, further, that this is very nearly the same for both stations below 200 m.; above this, on the other hand, we have considerably lower values at St. 144.

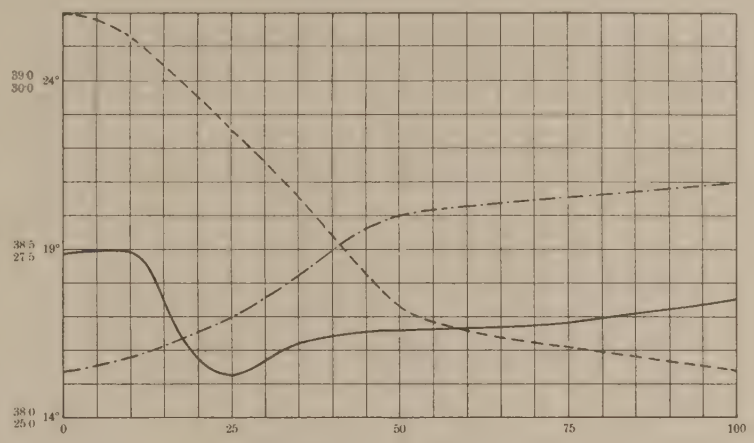

Fig. 11a. (St. 144).

The horizontal distribution of the temperature and salinity in the Ionian Sea can be seen from sections 3—5. The first of these extends in a northerly direction from the head of Sidra Bay to the

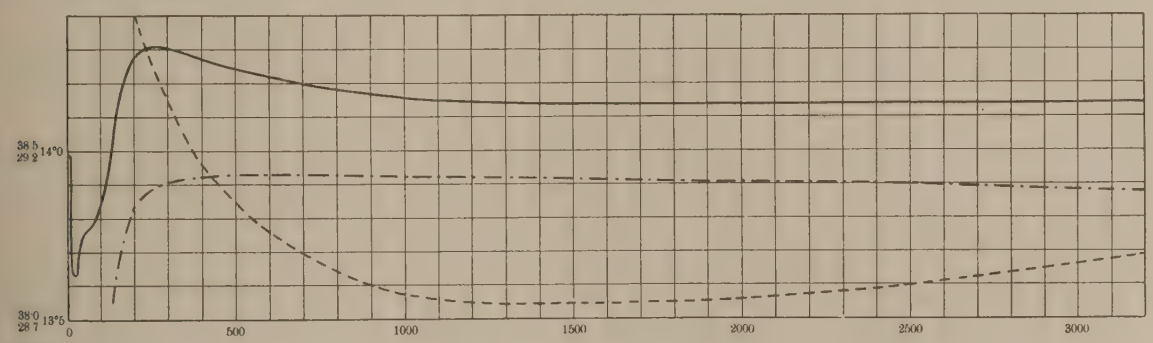

Fig. 11. (St. 144).

mouth of the Adriatic. The two stations 11 and 15, taken on the winter cruise of 1908, are included in this section, but no regard is paid to them in the isotherms for the upper layers, but for depths greater than 200 m. there seems to be a very good agreement between the values for the two different seasons. The lowermost part of section 3 has not been included, as the only curves present were the 13.7° isotherm at ca. 3300 m. and the 13.6° isotherm at 2500 m.; the uppermost 13.6° isotherm lies almost horizontally at ca. 1000 m., if we exclude the most southern part (St. 147), and we thus see, that there is in the Ionian Sea an extensive layer of water with extremely slight temperature gradient between 1000 and 2500 m. and with the minimum for the temperature about 1500 m. The lowest value for the temperature in deep water occurs, curiously enough, in the Sidra basin, where the

[1] The comparison of the curves for these stations has been made by drawing all the curves on tracing-paper with mm. divisions; in this way it is easy to combine any two curves by laying the one over the other and reading off the differences.

temperature at 950 m. was only 13.43°. From 1000 m. upwards the temperature rises, but we now notice some difference between the southern and the northern part, the isotherms towards the south lying somewhat deeper; thus, the 14° isotherm in the southern part lies about 400 m., whilst at St. 187 it is above 300 m. and at this last depth we still find a faint, intermediate temperature minimum.

This intermediate minimum in the temperature is found again in section 4 at all stations in the Ionian Sea from Greece to Sicily, but the depth at which it occurs is very different; whilst it lies at 300 m. (cf. fig. 12) at St. 187 about midway between Greece and Sicily, at St. 186 near Greece we find it already at 100 m. and at St. 189 south of Calabria it is at a depth of ca. 150 m. Regarding the course of the isotherms we may notice, that these, down to 15°, lie deepest in the middle of the section and approach nearer to the surface towards Greece and Sicily, whilst the 14° isotherm goes deepest down in the western part of the section; here, however, the temperature falls comparatively rapidly below 300 m., so that we meet with the 13.6° isotherm above 400 m., whereas the 13.6° isotherm sinks deeper down towards the east and on the east side lies at ca. 1100 m. We see, further, that the temperature at St. 189 is very nearly constant from 400 to 1200 m., and that we here below 1100 m. find temperatures less than 13.5° or almost the same temperature as that found at the bottom at St. 147 in Sidra Bay at a depth of about 900 m.

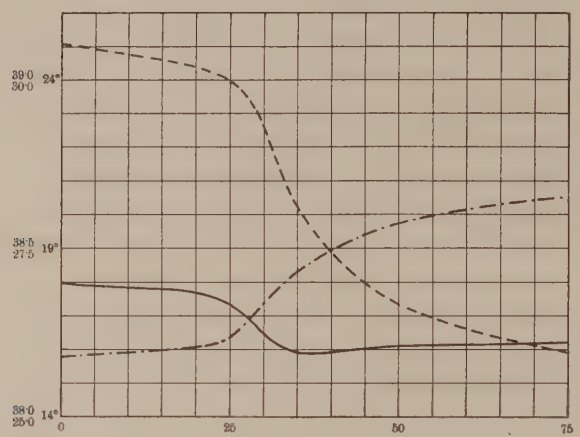

Fig. 12a. (St. 187).

Section 5, which extends over the Ionian Sea through the Pantellaria Channel to north of Cape Bon, shows that the isotherms lie somewhat nearer the surface south of Sicily; from there they go somewhat deeper down both to the east and west, though least to the west. In the western part we also find an intermediate minimum of ca. 13.7° at 175 m. and a slight minimum at St. 143 at almost the same depth, but the value here is a good deal higher, namely ca. 14.3°.

Considering now the vertical distribution of the salinity, we notice at once, that this has an intermediate maximum of 38.8 ‰ at a depth of about 300 meters in the centre of the Ionian Sea. From this depth the salinity decreases fairly rapidly upwards, but only slowly downwards, so that we find an extensive layer of water, which has a salinity of over 38.70 ‰, and we see that the thickness of this layer is scarcely 300 m. in Sidra Bay, but 500—600 m. in the centre of the Ionian Sea. Section 4 shows, that the thickness of this layer is ca. 500 m. at the Grecian coast, but that it decreases greatly towards the west, as can also be seen from section 5. We see, further, that the salinity of this intermediate layer decreases for the same level towards the west and that the maximum of the salinity is the same at the Straits of Messina as in the Pantellaria Channel, namely, very close to 38.70 ‰.

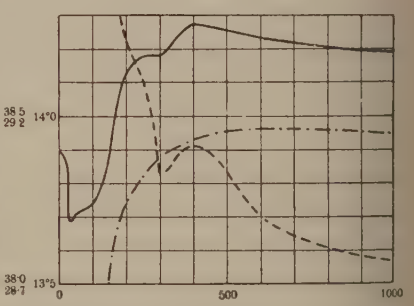

Fig. 12. (St. 187).

At depths greater than 1000 meters the salinity is almost quite constant, both vertically and horizontally, and has much the same value as in the Levant. The variations occurring are so small, that we cannot ascribe any real importance to them, all the observations lying between 38.64 and 38.68 ‰. The statements of the earlier authors (see KRÜMMEL [1907, p. 354]), that the variation of the salinity with the locality is not slight, are probably due to errors of observation or to less perfect methods of investigation. There is reason to suppose, for example, that the salinity of 39 ‰

found by the "Pola" Expedition at depths greater than 2000 m. was due to imperfect closing of the water-bottle; it was probably the same apparatus, which was used later in the investigation of the Sea of Marmora, and as we have already seen, the water-bottles used there have several times taken up surface-water when intended to sample the deep water.

On the other hand, considerable variations occur in the salinity of the upper layer of water, both from place to place and with the depth. Most stations in the Ionian Sea have however the common characteristic, that an intermediate minimum occurs at a greater or less distance from the surface. The value of this minimum varies with the position, but is always less than 38.25 ‰ except in the eastern part of section 5 A. The thickness of the layer in which the salinity is less than 28.25 ‰, is not over 30 m. in the centre of the Ionian Sea (St. 144), but we see from the three sections 3A—5A, that it increases to the west, north and south. At the very surface the salinity decreases most strongly towards the west, which is probably in part due to the fact, that the observations in section 5 were made earlier in the summer, in July, at a time when the salinity increases by almost 1 ‰ from the south-east point of Sicily to the middle of the Ionian Sea. The lowest value for the salinity at the surface occurs to the south-east of Sicily, and we even find here a layer of 50 m. in thickness which has a salinity below 37.50 ‰; this value rises naturally in the course of the summer, like the salinity of the surface-layer everywhere in the eastern Mediterranean. In the two other sections the salinity is not so low, but in both we find values below 38 ‰, in the southern part of section 3A (in Sidra Bay) and in the western part of section 4A (on the east coast of Calabria).

In the eastern part of section 4 I have included St. 184 in the Gulf of Corinth; the vertical distribution of the temperature and salinity at this station is also illustrated in fig. 7, p. 122. We see from the section, that the hydrographical conditions below 100 meters are very different from those found in the Ionian Sea, both the temperature and salinity being much lower than in the latter. From 200 m. the temperature is very nearly constant at 12.8° and the salinity likewise constant at 38.57 ‰, but the temperature has an indication of a minimum at 300—400 m., increasing 0.06° from there down to the bottom. In the neighbourhood of the surface the conditions are not specially different from those in the Ionian Sea, but the temperature and salinity are always a little lower than in the latter, and we find here as there a minimum in the salinity at ca. 35 meters.

Although the Gulf of Corinth belongs naturally to the Ionian Sea in hydrographical regards, we thus see, that it differs very essentially from this; but on considering fig. 7 p. 122 we find, that the constant layer in the deep water of St. 184 has a striking resemblance to the bottom-water at St. 183 in the Gulf of Aegina, where however both the temperature and salinity have slightly lower values. The cause of this uniformity has naturally nothing to do with the connection through the Corinth Canal, which must be considered to have no importance in this regard. The explanation is rather, that the Gulf of Corinth is also an independent basin as regards the deeper layers, and local causes are dominant there. The Strait of Patras, which connects the Gulf of Corinth with the Ionian Sea, has relatively shallow depths (less than 100 m.) and the water-masses in the Gulf of Corinth below this depth are naturally prevented from flowing out into the Ionian Sea, as they tend to do owing to their high density.

We can now readily understand the causes of the low temperature in deep water; in winter the surface-water of the Gulf of Corinth is cooled down, with subsequent vertical currents in the surface-layer, and when this cooling process has so far advanced that the density of the surface-layer is equal to the density in the uniform deep-layer, the latter will participate in the vertical circulation, which results in a water-layer with constant values for temperature, salinity and density right from the surface to the bottom. We see from fig. 7, that the salinity of the surface-layer is somewhat lower than that of the bottom-layer about the middle of August and even if the salinity of the surface-layer continues to rise until the rainy season sets in in autumn, a somewhat lower value than that in the deep water will

not prevent the convection currents arising, just as in the Black Sea and Sea of Marmora. With a salinity in the surface-layer like what we found in August a cooling of the surface to a little under 11° will produce a density, which is just as great as that found in the deep water, and as the mean temperature for January at Athens is 8.65° according to Éginitis [1896, p. 54], convection currents will arise almost certainly every winter and extend down to the greatest depths in this basin. That the vertical movements must be very active here, is also clearly seen from the high value for the percentage of oxygen occurring in deep water, a value which is almost as great as that found at St. 163 in the Aegean Sea. Owing to the shallow depths in the Strait of Patras an inflow of the saltest water-masses, which occur in the Ionian Sea (St. 186) at 150 m., is excluded and we can thus understand, further, why the salinity in the deep water is somewhat lower than in the Ionian Sea.

Even if the temperature at St. 183 in the Gulf of Aegina is almost the same as that at St. 184, yet it is worth noticing, that it is about 0.2° lower in the Gulf of Aegina, which agrees with what we have earlier pointed out, that the smaller the water-column, i. e. the depth is, the lower will be the deep-water temperature produced by the cooling in winter. It is far from being literally correct to say, that the deep-water temperature of an inland lake or closed basin is determined by the mean temperature in the coldest period of the year at the place in question, and it is evident, that the winter-temperature can as a rule only give a lower limit for the temperature in deep water.

The fact is, naturally, that when the whole water-column is cooled down to a definite temperature, it will be still further cooled in the cases where the air temperature is lower than that of the water and this lowering of the temperature will be inversely proportional to the depth. We see from this, that it might well happen also, that the temperature in a layer of water of relatively little thickness (e. g. about 50 m.) may become lower than the mean temperature of the air in the coldest month; it is conceivable, for example, that the mean temperature in the first half of the month was 10° and that a column of water of 50 m. was cooled down to about this temperature, then for a week a temperature of 0° occurred, and the whole layer of water was perhaps cooled to 9°; if then the air temperature during the last week rose to 20°, only the uppermost layer would be warmed up, whilst the temperature at 50 m. in a still layer would remain unaltered.

It will be seen from this, that such constant values for the temperature in deep water cannot be expected to remain constant from one year to another, and that we may expect that a rise of temperature will take place more slowly than a cooling, since the heating up of the deep water can only take place in many cases through a conduction of heat from the surface and from the bottom, whilst a cooling may occur as the result of a single, severe winter; but we have likewise seen, that the greater the thickness of such a layer of water, the less will be the single fluctuations, when all external circumstances are otherwise the same.

3. The circulation in the eastern basin of the Mediterranean.

a. Horizontal circulation.

We have seen earlier, that the fresh surface-water of the Black Sea, when it enters the Aegean Sea through the Bosphorus and Dardanelles, tends over towards the coast of Greece, along which it moves in a southerly direction; during this movement it becomes mixed with the salt water to so great an extent, that already at the south-east point of Euboa we find a salinity on the surface of over 36.5 ‰ and in the mouth of Aegina Bay 37.52 ‰. This flow of masses of fresher water with greatly increasing salinity towards the south has almost the character of a coastal current, which in consequence of the earth's

rotation is forced over to the right side of the basin in its course southwards, constantly tending more to the right as soon as the coast permits it. Thus, it passes between Morea and Crete and probably for the most part follows the west coast of Greece, going northwards, and we can still detect it apparently in section 4 by a somewhat lower salinity of ca 38.2 ‰ in the eastern part of the section, at St. 186, whilst the surface-salinity a little to the west of this is 38.5 ‰.

In the eastern part of the Aegean Sea the salinity in the surface-water is very high — over 39 ‰ — and, as we have already seen that salt masses of water flow from this Sea through the Dardanelles already at a depth of 15 m. under the surface, it is evident, that the salt water from the Levant passes through the Aegean Sea on its way to the Dardanelles and thence further to the Sea of Marmora and the Black Sea. In contrast to the current along the Grecian coast this north-going current of very salt water-masses has a secondary character, being in the nature of a compensation-current, and will keep to the right side of the basin, thus along the coast of Asia Minor, in consequence of the earth's rotation. We see, therefore, that the movement of the surface-water in the Aegean Sea has in the main the character of a cyclonic rotation and that the water-masses taking part in it on the east side have a very high salinity (about 39 ‰), which is almost constant to near the entrance of the Dardanelles, whilst the salinity on the west side is low and increases from 22—23 ‰ at the Dardanelles to 37.5 ‰ in the mouth of the Gulf of Aegina at Cape Colonna and probably to about 38 ‰ at the south point of Greece. To the south this movement of rotation is interrupted, the Grecian coastal current bending towards the west between Morea and Crete and leaving the Aegean Sea, whilst the north-going compensation-current, as we shall see later, must be considered to run into the Aegean Sea from the south-east.

The salinity of the surface-water is probably subject to great fluctuations in the course of the year, especially in the Grecian coastal current, where it must be considered to have its highest value in the coldest season of the year, when the outflowing, fresher surface-layer will become mixed with deeper, salter masses of water by means of vertical currents. We find, for example, that the salinity of the surface-water in the Gulf of Aegina on Dec. 30th 1908, St. 18, was relatively high 38.40 ‰ and was almost constant down to ca. 80 m. The minimum will probably set in some few months after the maximum, namely, as soon as the vertical circulation in the surface-layer comes to an end, in consequence of the gradual rise of temperature, and this will take place almost at the maximum inflow of freshwater into the Black Sea.

It is known from the older Austrian investigations with the "Hertha" [Wolf & Luksch, 1881], that considerable quantities of comparatively fresh water flow out through the Straits of Otranto into the Ionian Sea as a surface-stream in the western part of the Straits, whilst there is a high salinity at the surface in the eastern part. We see from Sect. 4 A, that there is an intermediate layer of water with low salinity to the south-east of Calabria (at St. 189 it is even below 38 ‰), a layer of water whose existence is not apparent from the salinity at the surface, where we find 38.30 ‰ as the result of evaporation, and there is no doubt, that this is the water flowing out of the Adriatic Sea. The cause of this outflow must be sought for, just as in the case of the Black Sea, in the differences of level and pressure, thus, in the end, in a difference of density resulting from the extensive mixing with freshwater in the northern part of the Adriatic, chiefly from the North Italian rivers. As this fresh water, however, leaves the Adriatic as a mixed product with relatively high salinity, this loss of salt must be compensated for by an inflow of salter water-masses, either at the surface in the eastern part of the Straits of Otranto or in intermediate layers below the outgoing surface-current. Wolf and Luksch have demonstrated the existence of this inflow on the surface, and we thus see, that the horizontal circulation in the surface-layer of the Adriatic is quite analogous with what occurs in the Aegean Sea.

We might expect beforehand, that the south-going surface-current will be inclined to the right as

the result of the earth's rotation and will thus flow out of the Ionian Sea through the Straits of Messina and the Pantellaria Channel. Very powerful currents exist in the Straits of Messina, but the extensive literature on the subject shows, that these are mostly tidal currents and not a steady transport of large masses of water in the same direction, such as we find, for example, in the Straits of Gibraltar. From St. 192 between Messina and Reggio di Calabria we see also, that the minimum salinity here is relatively high, so that there can be no talk of any great outflow of the fresher surface-layer through the Straits of Messina, if indeed this occurs at all [1].

Nor do the fresher masses of water from the Adriatic seem to leave the eastern basin of the Mediterranean through the Pantellaria Channel; the peculiar distribution of salinity in Sect. 5A seems to show, that these water-masses are not bent by the earth's rotation towards the west along the the south side of Sicily, since, if this happened, we should expect to find almost just as low values for the salinity at St. 141 as at St. 142, and we might especially expect an intermediate minimum of salinity just as at the station last-mentioned. It is well-known, however, as we shall also see later from section 6, that between Cape Bon and Sicily a comparatively fresh surface-current flows into the eastern basin of the Mediterranean, namely, a continuation of the Atlantic current through the Straits of Gibraltar and it is therefore reasonable to suppose, that the comparatively fresh masses of water from the Adriatic, after flowing along the east coast of Calabria and Sicily, leave this in a south-westerly or southerly direction and then after uniting with the Atlantic water bend towards the east along the coast of Tripoli, where at St. 147 in Sect. 3A we find again an intermediate minimum for the salinity of under 38 ‰. From Sect. 2A also it will be seen, that this layer of water extends further east along the coasts of Barka and Egypt, where it is still very distinct in Sect. 1. — The salinity, which has greatly increased from Cape Bon and the south-east point of Sicily to Barka, increases further towards the east along the Egyptian coast, but after mixing with the water of the Nile a lower salinity is found, according to Luksch & Wolf [1893, Charts X and XI], along the coast of Syria as far as Asia Minor, where it is gradually lost in the salt water-masses towards Rhodes, but we may regard as a continuation of this coastal current the salt masses of water which flow towards the north in the eastern part of the Aegean Sea.

The distribution of the salinity in the eastern basin of the Mediterranean thus shows, that a current of fresher masses of water flows along its coasts in a cyclonic direction; the depth of this current is somewhat variable, but at places it may reach down to 200 m. in the neighbourhood of the coast, from which the thickness decreases out towards the middle of the basin. The largest contribution to this less saline, coastal current is certainly made by the Atlantic water which runs in through the Pantellaria Channel, but we have seen, that important contributions are given by the rivers, which flow out into the Adriatic and Black Sea and lastly by the Nile. That the fresher water does not spread out over the whole of the basin, which it would be disposed to do from its lower density, is due in the first place to the earth's rotation, which bends the current to the right and thus forces the inflowing Atlantic water up against the coast of Africa and constantly maintains the current-system described above. As very considerable differences in density occur and consequently differences in hydrostatic pressure (for example between St. 156 and St. 158 in Sect. 1), we might conclude, that this coastal current flows with a considerable velocity, as the force arising from the difference in pressure must be held in equilibrium by the deflecting force of the earth's rotation, which is proportional to the rate of flow of the current; the prevailing north-west winds also contribute probably to keep the east-going masses of

[1] From some investigations made in the Straits of Messina in 1908 Marini [1909] found some very low values for the salinity in the neighbourhood of the surface, but a close consideration of the values found for the salinities in depths about 200 m. shows that these are on the whole much too low; at 200 m. the salinity is scarcely ever lower than 38.5 ‰ whereas Marini for his St. III (12/6 1908) gives a salinity of 37.01 and a temperature of 17.90°, in 50 m. respectively 37.46 ‰ and 15.10°; the impossibility of this distribution is obvious. It is thus hardly permissible to conclude from these low values for the salinity in the surface-layer, that the latter comes from the Adriatic.

water along the coast of Africa, but it is difficult to form any estimate of the amount of this contribution.

Excluding the northern part of the Levant, the cyclonic current-system described above consists of less saline masses of water and may be considered as restricted to the latter, so that the extent of the current-system is the same as the thickness of the fresher water-layer, and this is greatest, as we have seen, on the south side of the basin, where it is about 200 m. in Sidra Bay, whilst on the north side it scarcely exceeds 100 m. Various conditions indicate, that below the less saline surface-layer, there is a transition-layer, in which the movements are somewhat different from those in the surface-layer. We have shown, for example, that over the whole of the Ionian Sea there is an intermediate maximum of the salinity at a depth of ca. 300 m. below the surface, and that the salinity decreases greatly upwards from this maximum, whilst the variation downwards is very slow; this maximum cannot be considered to have arisen in the Ionian Sea by the concentration of the surface-water from evaporation, as its value far exceeds the salinity at the surface and even if this increases in the course of the summer, the high salinity at the surface will be separated from the intermediate minimum at about 300 m. by a fresher layer of water.

The only possible explanation of the occurrence of this maximum is, that it arises from an outflow of salt masses of water from the Levant, as this is the only place where such a high salinity is found. From the various sections through the Ionian Sea we see also, that the salinity has its highest value in the middle of this Sea, where we find 38.80 ‰, and that the thickness of the water-layer with a salinity over 38.70 ‰, as is shown by sections 3 and 5, decreases from the middle of the Ionian Sea towards the south, west and north; at St. 15 in the Straits of Otranto the maximum of the salinity has decreased to 38.73 ‰, towards the Pantellaria Channel it decreases to 38.70 ‰, and west of Cape Bon the maximum is 38.68 ‰. This distribution of the salinities in the intermediate layer, a maximum which gradually increases towards the Levant, thus agrees very well with the idea, that this water-layer comes from an intermediate outflow from this Sea, and that the outflowing salt masses of water, during their movement through the Ionian Sea, gradually become mixed with less saline water.

This distribution of salinity is not difficult to explain if we start from the fact, that water of relatively low salinity goes into the eastern basin of the Mediterranean as a surface-current between Sicily and Tunis. If we take the weight of the quantity of water which flows in through this section in the course of the year as I kg., and take the average salinity of this as 37.2 ‰, a value that is not too high at any rate, as we see from the sections from Sardinia and Sicily to Tunis, then in the course of one year the eastern basin of the Mediterranean receives a quantity of salt equal to $37.2 \times I$ gm. and if we suppose the condition to be stationary — which is a necessary assumption — then this quantity of salt must be given up again by outflow from the basin. If U is the outflow and F the total addition of fresh water to the eastern basin of the Mediterranean (including here the Black Sea), and E is the evaporation from the surface in one year, then the equation

$$(1) \qquad F + I\,(1 - 0.0372) = E + U\,(1 - \frac{S}{1000}),$$

where S is the salinity of the outflowing masses of water, indicates, that the quantity of fresh water which the eastern basin of the Mediterranean receives in the course of a year is equal to the quantity lost, or that the level of the Mediterranean does not change from one year to another (the correctness of the equation does not exclude an annual periodicity). In addition to this equation of continuity, which is based on the assumption of constancy in the amount of water during the time considered, the equation

$$(2) \qquad 37.2 \times I = SU$$

is an expression for the continuity in the amount of salt and means that this is constant from one year to another, or that the quantity of salt, which is added to the eastern basin of the Mediterranean in the course of one year, is again carried away by the outflowing masses of water.

If we now consider the three stations 160, 144 and 138, we see, that the density at the same level decreases from east to west, and if we calculate the pressure on a unit of surface at a certain depth d cm., this is determined by $p = d\rho g$, where g is the acceleration of gravity and ρ the average value of the density in the water-column lying above; the difference of pressure between two of the stations is then $\Delta p = dg\ (\rho_1 - \rho_2)$. In this calculation we can exclude the compressibility, as the increase in density produced by it is very nearly the same at the same depth at the three stations considered and as the uncertainty thus introduced in the differences of density is small, in comparison with that which arises from the unequal variation in the density between the points, in which this is determined [1].

Calculating now the difference in pressure at a depth of 400 m. in this way, we obtain $\Delta p_{(160-144)} = 9.4g$, $\Delta p_{(144-138)} = 2.8g$ and $\Delta p_{(160-138)} = 12.2g$. At a depth of 300 m. the difference in pressure is very nearly as great as the above values, as there is only a slight difference in the density at depths from 300 to 400 m. On the water-particles occurring at this depth a force will then act in the direction towards the west, or if we imagine a niveau-plane at St. 160 at a depth of 400 m. parallel with the theoretical surface of equilibrium (the surface the sea would have, when the water everywhere at the same depth had quite the same properties and was at rest), then the distance of the surface from this niveau-plane at St. 138 would be about 12.2 cm. or more exactly (as σ_t for the surface-water is 25.76) $\frac{12.2}{1.02576}$ cm. greater than at St. 160. This difference of level will tend to adjust itself by means of a current-system, which on the surface is directed from St. 138 towards St. 160 and at depths of down to 400 m. in the opposite direction. The east-going surface-current is inclined to the south-east towards the coast of Africa by the earth's rotation and there it is kept within fairly narrow limits, from which we may conclude, as we shall see later, that it has a relatively high velocity; the west-going, intermediate current, which on the one hand has a greater thickness and on the other extends over the whole of the Ionian Sea, must on the other hand be considered to have a lesser rate of flow in consequence of the wide cross-section, the deflecting influence of the earth's rotation being relatively slight for these water-masses, though it cannot be considered to have no importance for the direction of movement.

This circulation however does not adjust the differences of pressure and level, which produced it; the intermediate, salt water-masses flow out into the western basin of the Mediterranean through the channel, which cuts the ridge between Sicily and Tunis at a depth of about 400 m., and spread out in the western basin, as we shall see later, whilst the fresher masses of water flowing to the east on the surface gradually become concentrated to a salinity which is at least just as great as that of the outflowing masses of water, and as new masses of water with low salinity are constantly running in from the Atlantic, we see, that this difference in density and the consequent difference in level is a stationary condition, on which the circulation in the upper layers of the eastern basin of the Mediterranean depends.

Section 6 shows, that the salinity 38.68 ‰ in the uniform bottom-layer at St. 138 and 139 is very nearly the same as that we find in the intermediate layer in the western part of the Ionian Sea, so that

[1] From Ekman's "Tables for Sea-water under pressure" [Ekman 1910] it appears, that the value by which σ_t should be corrected to give the density *in situ* at a temperature about 14° and in a depth of 400 m. (the greatest depth in question here) scarcely varies 1 in the 5th decimal of the density for a change of temperature of 1°. As the difference in temperature at depths below 100 m. is much less than 1° for the three stations considered, it will be seen, that the calculation of the density *in situ* is in reality quite superfluous in this case.

the salinity of the outgoing under-current in the section from Cape Bon to Sicily may be taken to be 38.7 ‰. From the continuity equation (2) we then have:

$$(3) \qquad \frac{I}{U} = \frac{38.7}{37.2} = 1.040$$

From the continuity equation (1), which with the help of (2) reduces to;

$$(4) \qquad F + I = E + U$$

we obtain on using (3):

$$F + I = E + \frac{I}{1.040} \text{ or}$$

$$(5) \qquad 0.0385 \times I = E - F$$

From this equation we see, that $E—F$ is positive, thus that the quantity of water lost by evaporation is greater than the total addition of fresh water, which is also apparent indirectly from the equation (3) and is indeed obvious beforehand from the simple fact, that the salinity of the surface-water increases towards the east the whole year round. From the equation (5) it is further seen, that the excess of evaporation over the fresh-water supply only amounts to a little under 4% of the inflow from the western basin of the Mediterranean, which means therefore, that about 4% of the inflowing water-masses is evaporated in the eastern basin, whilst ca. 96% is again carried out in concentrated condition by the under-current flowing through the Pantellaria Channel. Lastly, we see from (5), that the inflow must have an annual period; in summer, when the rainfall over the eastern basin is extremely small and is only of importance in the case of the Black Sea, and when the amount of river-water is at a minimum, whilst the evaporation increases with the temperature, $E—F$ reaches its maximum; and even if the inflow, as secondary phenomenon, must be considered to be somewhat later in phase by comparison with $E—F$, it will probably attain its greatest strength late in summer or beginning of autumn, at which time the total quantity of salt will probably have its maximum, decreasing thereafter in the course of the winter. As the causes which produce a stronger inflow, will also lead to a greater outflow, it is probable, that the inflowing water-masses will not attain to any appreciably greater extension in depth in the Pantellaria Channel than that found, but that the greater exchange of water will show itself in an increase of the velocity of the current.

In the preceding pages we have discussed the horizontal circulation in the surface-layer, which is in the main a cyclonic rotation, and in the intermediate layers, where it is mainly a movement westwards towards the Pantellaria Channel (the measurements made in the neighbourhood of the Straits of Messina, especially at St. 192, show, that the salt water-masses lie so deep, that there can be no question of their flowing out through the Straits of Messina); the intermediate, west-going layers are possibly also subject to some extent to the deflecting influence of the earth's rotation, but not nearly to the same degree as the surface circulation, which is probably connected with a many times less velocity in the intermediate water-masses. In the lowermost part of the latter the salinity decreases slowly, so that this layer grades evenly into the bottom-water, where the salinity is almost quite uniform, the values for the Ionian Sea and the Levant all lying between 38.64 and 38.68 ‰; there is thus no sharp transition between the bottom-water and the intermediate layer, such as there is between the latter and the surface-water, but we may conclude, that the boundary lies at the depth in which the salinity gradient becomes 0 (a little below 1000 m.), which is almost the same depth as that in which the temperature gradient changes sign.

In the bottom-water also we must conclude that horizontal movements occur to a by no means inconsiderable extent. As we shall see below in discussing the vertical circulation, we must conclude, that a cooling of the bottom-water takes place in the northern part of the Ionian Sea and Levant, whilst such

a cooling process is wanting on the south side, where on the contrary there might be talk of a warming process from prolonged conduction of heat. This cooling on the north side of the basin is also accompanied by a partial renewal of the amount of oxygen absorbed in the bottom-water, whilst a renewal of the oxygen used in the deep water on the south side of the basin can only occur by diffusion of the air through the upper layers, a process, which, as we see from the condition in the Black Sea and Sea of Marmora, is unable to keep the oxygen content at the level found in the deep water of the Mediterranean. If no horizontal movements occurred in the bottom-water, we should expect, that the temperature in the southern part would be higher than in the northern part of the basin, whilst the absorbed amount of oxygen would decrease from north to south; but if we consider the sections 1 and 3, we find no such rise of temperature towards the south at the same level, and just as little a reduction in the amount of the absorbed oxygen. Towards the southern part of Sect. 3 (at St. 147) the variation even tends in the opposite direction, the temperature decreasing a little towards the south and the percentage of oxygen increasing.

The fact, that the temperature of the bottom-water is practically constant in a horizontal direction — and, as earlier assumed, also in a vertical direction, though not even approximately to the same extent — has been put forward by the earlier authors as evidence, that this bottom-water was quite or almost quite at rest; it seems to me, however, that from this same fact we may with equal right draw the conclusion, that the bottom-water could not be at rest. Choosing an analogous case from experimental physics, it is well-known, that if we wish to keep a large body of liquid at a constant temperature we must keep it in fairly rapid motion; and, on the other hand, if such a liquid has everywhere the same temperature, though exposed on the one side to heating and on the other to cooling then it is evident, that movement and mixing of the different parts must be going on. The latter case is analogous with the condition in the deep water of the Mediterranean, in which, therefore, we must conclude, that a fairly active exchange of water-masses must be going on between the northern and southern parts.

How this movement takes place, cannot be determined in details from the available material, especially as the variations in the dimensions measured are so extremely small from place to place. I may just note, however, that we find just as low values for the temperature in deep water at St. 189 southeast of Calabria as at St. 147 in Sidra Bay; at the latter place the lower value in deep water cannot possibly have arisen from a cooling process starting from the surface. There is no doubt, therefore, that these water-masses in Sidra Bay must have come from the northern part of the Ionian Sea, to which, as we shall see below, they have probably come from the southern part of the Adriatic. These colder masses of water are only found in the western part of Sect. 4, thus indicating, that there is a current in deep water coming from the Adriatic, which is directed towards the south and keeps to the western side of the Ionian Sea, bending later towards the east on the south side; this is therefore a cyclonic rotation, analogous with the movement in the surface-water. As there is a small difference in the temperature at great depths between the Ionian Sea and the Levant, which is due to the presence of the submarine plateau between Barka and Crete, there is further reason to believe, that the circulations in the deep water of the Ionian Sea and the Levant are in part independent and separate, at least for depths greater than 2000 m.

b. Vertical circulation.

In preceding pages the vertical circulation and the ventilation of the deeper layers, which is dependent on it, has repeatedly been referred to. We have seen, for example, that in the Black Sea the vertical circulation extends from the surface down to a depth of ca. 100 m. only, whilst the bottom-water, which is at places over 2000 m. deep, is essentially dependent for its renewal of oxygen on the inflowing salt masses of water from the Sea of Marmora, and this inflow is not sufficient to compensate for the

oxygen used up, so that an excess of hydrogen sulphide has been formed in the course of time from the decomposition processes in deep water.

In the Sea of Marmora ventilation from the surface is also excluded owing to the presence of the fresh and light surface-layer, but as the Sea of Marmora is rather to be regarded as a reservoir for the Black Sea, and relatively considerable masses of water flow through it, the percentage of oxygen is maintained above the limit necessary for the presence of organic life. The inflowing masses of water from the Aegean Sea are able in winter to penetrate to the greatest depths in the Sea of Marmora, whereas the vertical circulation from the surface is restricted to the fairly fresh surface-layer, the thickness of which is normally about 20 m.

In the Aegean Sea on the other hand — at least in the eastern part, where the salinity at the surface is high — we have seen, p. 122, that the necessary conditions are present for a vertical circulation from the surface through the whole of the water and there is no doubt, as can be seen from St. 163, that a ventilation of the whole body of water in the deep basin north-east of the Cyclades has taken place in the winter of 1910. It is also not at all probable, that the winter would ever be so mild, that such a vertical circulation could not occur. Further, in the innermost part of the Aegina Bay, where however the fresh water-masses are in evidence in the surface-layer, we have seen, that the vertical circulation may extend through the whole body of water, and in Corinth Bay we have also found a bottom-layer with distinct traces of a considerable ventilation, namely, constant salinity, low and almost constant temperature and high percentage of oxygen.

With regard to the Adriatic, we have no direct evidence, that the vertical circulation in this Sea extends through the whole body of water, but there can be no doubt, that this is the case. St. 15 in the Straits of Otranto, investigated in December 1908, shows on the one hand a high value for the absorbed amount of oxygen in the bottom-water and on the other a salinity of 38.24 ‰ in the surface-layer; a cooling to ca. 12° will thus give the latter just as high a density as the bottom-water has; in reality a less cooling will be sufficient to bring about this process, as the salinity of the surface-layer will gradually increase on its becoming mixed through vertical circulation with the salter layer, which is found from a depth of 100 m. The earlier mentioned, temperature observations of Hopfgartner to the south-west of Ragusa, in the deep basin south of the threshold Cazza-Pelagosa-Pianosa, show for example a temperature which is only a little over 12° even at depths greater than 1000 m., and though this value must be considered to be unusually low — Wolf and Luksch [1881] give the temperature in the deep water of this basin as 12.8° — it is yet reasonable to conclude, that the cooling of the surface in the Adriatic is much greater than the cooling of the regions much further to the south, in Corinth Bay and the Aegean Sea, and that the vertical circulation from the surface will in the course of the winter extend down to the greatest depths. During this circulation the salinity will gradually become uniform in the whole body of water, but as this process is restricted to where the salinity at the surface is beforehand somewhat high — e. g. on the east side of the basin — the salinity in the bottom-water will not be appreciably reduced (at St. 15, for example, a mixing of the whole body of water will give a product with a salinity, which is only 0.03 ‰ lower than that of the bottom-water). It follows from this, that the density of the cooled body of water will be somewhat greater than that which is found in the bottom-water of the Ionian Sea, analogous with what we have shown in the case of the Aegean Sea.

Whilst it is thus certain, or exceedingly probable, that the vertical circulation will extend right down to the bottom in the Aegean Sea and Adriatic, the conditions seem to be somewhat otherwise in the Ionian Sea and the Levant. In the Ionian Sea the salinity at the surface is fairly low, so that any sinking of the uppermost layer can only be produced with difficulty and must be regarded as quite impossible in the southern part especially; this applies also to the southern part of the Levant. In the

central and northern part of the latter, the salinity, as we have seen, is very high and here a sinking down of the uppermost layer is beforehand very probable.

It is very doubtful, however, if this sinking extends in general right down to the bottom-water in the Levant. In the case mentioned by MAKAROFF (see p. 94) the temperature from the surface to over 100 m. was still over 16° about the middle of March, from which it follows, that the exchange of water between the surface and the bottom-layer had not already taken place in the preceding winter months, and it must be considered as excluded, that this will occur after the middle of March, as it could only take place after a loss of heat amounting to over 20,000 gm.-calorics per square cm. of surface or almost half the amount of heat which is given off in the course of the winter. We have seen further, that however different the distribution of the salinity may be at different stations in the Ionian Sea and in the Levant, yet they also show an appreciable decrease of salinity in depths about 800 m., and in the extensive layer of water from the surface down to this depth both the salinity and temperature vary very considerably, which will certainly not permit us to conclude, that this layer and the bottom-layer have taken part in the same convection movement.

There is no doubt, as mentioned, that an intensive sinking of the water from the surface takes place in the Levant, nor is it excluded, that the cooling in winter may be so great, that this sinking may extend right down to the bottom and set up a vertical circulation throughout the whole body of water, but it is probably only in extraordinary cases, namely in specially cold winters, that this occurs. Both at St. 158 and 160 we have signs of a uniform temperature and salinity from 175—200 m., and I am inclined to believe, that we have here the lower limit for the direct vertical circulation from the surface, which occurred in the winter of 1909—1910. On the other hand, the water-masses sinking down from the surface will in general, as I have explained above p. 135, move towards the west as an intermediate current and leave the eastern basin of the Mediterranean through the Pantellaria Channel.

As the density below the uppermost layer which is warmed up in the course of the summer (that is, in depths below 100 m.) varies very slightly, we see, however, that a slight increase of the salinity or a slight reduction of the temperature will cause the intermediate masses of water to sink further down, and as the salinity at the surface gradually becomes greater than in the lower layers, a transport of heat will then take place to the deeper layers by cooling of the surface water analogous to what I have shown above p. 123. There seems to me no doubt, that the whole layer of water in the Levant down to ca. 1000 m. has assumed a temperature somewhat higher than that of the bottom-water by mixing processes during such a slow partial sinking of the water from the upper layers, as it is probably only exceptional, that this sinking becomes so intensive, that it produces a vertical circulation through the whole body of water. In the Ionian Sea, where the temperature down to ca. 1000 m. is also higher than in the bottom-water, this arises on the other hand, not from any influence from the surface, but from the influence of the intermediate, west-going current, which comes from the masses of water sinking down from the surface in the Levant. The centre of these lies here at a depth of ca. 300 m. and it is also probable, that a slow sinking goes on from these salter and warmer masses, produced possibly by a slow cooling of the intermediate layer, so that the intermediate layer plays the same role here in the Ionian Sea as the surface-layer in the Levant, for the distribution of temperature and salinity in the layer which forms the transition to the bottom-water.

There can be no doubt, that the higher temperature from the surface down to a depth of about 1000 m. does not arise from heat descending from the surface during the preceding part of the summer; as the minimum temperature is found at a depth of 1200—1500 m, it would be necessary, namely, to assume, supposing that the whole body of water has had the same temperature in the preceding winter, that the heating process had reached down to a depth of over 1000 m. in the period from March to the end of July,

an assumption that is obviously improbable. I am much more disposed to believe, as the above discussion will have shown, that the temperature in the layer of water down to something over 1000 m. has been produced by the vertical circulation from the surface during several years, and that the circulation which has occurred in the winter of 1909—1910 has not extended deeper down than to a little over 200 m. With greater cooling at the surface the vertical circulation will extend deeper down, but it is probably quite exceptional for the whole body of water from the surface to the bottom to take part in the same vertical movement.

As we must conclude, therefore, that the periodic warming and cooling of the surface only affects the vertical distribution of temperature down to depths of a little over 1000 m., the question arises, what are the factors which determine the temperature in the bottom-water, which is at places over 2000 m. in extent. The assumption is not very unreasonable in itself, that the whole body of water had been cooled during a specially cold winter, which must then have occurred several years previously [1], whilst the vertical circulation in the subsequent years had been restricted to the higher layers, but there are several conditions which point in an opposite direction. Thus, the absorbed amount of oxygen has a minimum, which is almost at the same place as the temperature minimum, and thereafter increases appreciably down towards the greatest depths; this distribution cannot be explained by the assumption of a vertical circulation from the surface through the whole body of water, as such a ventilation should result in an almost uniform amount of oxygen in the bottom-water with an increase towards the surface, just as we find at St. 163.

We have seen, further, that a uniform layer of water from surface to bottom occurs in the southern part of the Adriatic and in the Aegean Sea north of the Cyclades — possibly also in the deep water north of Crete — and that this layer is colder and heavier than the masses of water, which are found at the same level in the Levant and Ionian Sea. These masses of water will then move towards the south, in the extent to which the depths permit, and after reaching the Ionian Sea and Levant will flow down its northern slopes to the greatest depths. During this movement they will become partially mixed with the bottom-water and be distributed by horizontal currents in the bottom-layer over the whole of the eastern basin. As these colder masses of water from the Adriatic and the Aegean Sea contained a large quantity of oxygen, in consequence of the ventilation from the surface in the course of the winter, we can now also understand, how the increase in the amount of oxygen in the bottom-water in the eastern basin of the Mediterranean has arisen and been maintained, and we thus see, that the ventilation of the bottom-water does not proceed directly from the surface but from a mixing with the oxygen-rich masses of water from the northern border-regions.

We can now readily understand, why the absorbed amount of oxygen has an intermediate minimum; in the uppermost part of the bottom-water the ventilation is least and the transport of oxygen to the lowermost part of the intermediate layer, in which the ventilation takes place from the surface, is likewise small, so that we find a minimum in the amount of oxygen on the boundary between these two layers of water. As the oxygen minimum lies very nearly at the same depth as the intermediate temperature minimum, at which depth the salinity (reckoned from the surface) becomes constant, we come again in this way to the same boundary for the bottom-layer as we have indicated earlier, but round about this boundary there

[1] The calculations which have many times been made with regard to the conduction of heat through a mass of water from its surface would give for this case the result, that several thousands of years from the time when the whole body of water had a constant temperature, would be required to produce the distribution of temperature found. It is obvious, however, that such calculations will as a rule be of no practical importance, as a necessary assumption in them is, that the water-mass is stationary, and in this case especially the result would be quite illusory owing to no attention being paid in these calculations to the peculiar conditions, which arise from evaporation of the surface water; as we have seen earlier, a cooling of the concentrated surface-water will produce a transference of heat to deep water, which under favourable conditions would extend down to depths hundreds of times greater than the calculated.

is a layer of water of several hundreds of meters in thickness, in which the vertical variation in the dimensions measured is exceedingly small.

The volume of the water-masses cooled down in the northern border-regions, which will flow out into the eastern basin of the Mediterranean, is dependent on the depth over the thresholds towards this basin. In the case of the Adriatic this depth is about 900 m. in the Straits of Otranto; for the northern part of the Aegean Sea it is about 400 m., which is the maximum depth west of Nicaria, whilst between Crete and Scarpanto the depths are considerably greater. When the cooled masses of water flow towards the south in deep water, in the course of the last half of winter and spring, they must be compensated for by a surface-inflow of water-masses from the south, which consequently have a higher temperature than the outflowing water. Thus, the explanation of the fact, that we found an unusually high temperature at St. 163 north of Nicaria down to about 400 m., is clearly, that these masses of water have flowed in here from the Levant as compensation for a layer of water ca. 400 m. thick, which has moved towards the south with a temperature of the same dimension as that of the bottom-water, namely, ca. 13.3°.

VI. The temperature at great depths.

We have seen in the foregoing, that there are two essentially different layers of water in the eastern basin of the Mediterranean, one layer from the surface to somewhat over 1000 m., in which the distribution of temperature is a consequence of successive heating and cooling of the surface, and a bottom-layer which we may estimate to extend up to about 1200 m. from the surface. In reality it is only in the northern and central parts of the Levant, that the conditions are so simple. In the southern part and in the whole of the Ionian Sea we find, that the upper masses of water consist of two essentially different and fairly well-marked layers, as a surface-layer also appears here with a thickness of 150—200 m. and a relatively low salinity; below this we have an extensive intermediate layer of water-masses analogous with those in the central and northern parts of the Levant and coming from the latter. In the bottom-layer, on the other hand, the temperature is determined by the inflow of colder masses of water from the Aegean Sea and the Adriatic. This inflow raises the upper layer a little and the transport of heat, which will necessarily take place between the latter to the uppermost part of the bottom-layer, is thus probably compensated, so that the boundary between these two layers will probably remain to some extent unchanged during a long perid of time, except in the case, which cannot be considered as quite excluded beforehand, when the surface is so much cooled down, that the water-masses from the upper layer become mixed with the bottom-water by means of vertical currents.

A factor we cannot quite exclude, when it is a question of the temperature of the bottom-water, is the conduction of heat from the interior of the earth. The somewhat variable values for the temperature gradient in the uppermost part of the earth's crust [Thiene 1907, p. 38] give about 1° C. per 33 meters, and if we assume, that the amount of heat passing through a unit of surface of the sea-bottom in the course of a year has the same value as the mean gives by Hann [1901, p. 741] for the land-surface, namely ca. 40 cal., then this amount of heat would be able to warm up a layer of ca. 4 m. in thickness by 0.1° in the course of a year. If we imagine now, that the bottom-layer originally had a uniform temperature and salinity, and no movement occurred in it, the equilibrium would be disturbed by this heating from the bottom and ascending currents would arise without meeting any other resistance than the inner friction in the water-masses themselves. Since, further, the transport of heat from the sea-bottom would proceed quite uniformly, we should expect, that the heat would spread upwards in such a manner, that

the temperature rises down towards the bottom and a stationary condition ensues with a constant temperature-gradient.

As we have seen in the foregoing, the temperature in the deep water of the eastern basin of the Mediterranean — and also in the western, as we shall see later — has its lowest value in the uppermost part of the bottom-layer, from which it rises fairly evenly towards the bottom. At St. 160, for example (fig. 8, p. 126), the temperature rises from 1000 to 2975 m. by 0.18°, and if we assume, that this rise of temperature has been produced by transport of heat through the sea-bottom, then the value given above for the yearly transport of heat gives a period of ca. 250 years for this purpose[1]. Since, however, the amount of free oxygen in the bottom-water is fairly high, which points to its frequent renewal, and we have also seen above, that new masses of water are added yearly to the bottom-layer from the northern border-regions, we are obliged to reject the submarine heat as the cause of the rise of temperature towards the bottom.

The cause of this characteristic distribution of temperature is indeed much nearer to hand. In discussing the methods of measuring the temperature it has been mentioned, p. 106, that when a quantity of water inclosed in an insulated water-bottle is hauled up from deep water, the temperature of the water will decrease in consequence of the adiabatic expansion produced by the diminution of pressure. According to Lord Kelvin [1857] this loss of heat is determined by the formula:

$$\frac{dt}{dp} = \frac{e\,(t + 273)}{c_p \cdot \rho \cdot I}$$

where t is the temperature in Centigrade, e the coefficient of expansion at the temperature t and the pressure p, whilst c_p is the specific heat at constant pressure, ρ gravity and I the heat equivalent.

In his experiments on the compressibility of sea-water Tait [1889, p. 52] found good agreement between the calculated and observed values for the change of temperature under variation of pressure, and from Tait's observations Ekman [1905], who has later made the compressibility of sea-water the subject of a renewed investigation [1908], calculated the values for dt for different values of t and dp, regard being taken for the variations in e and c_p with the pressure. According to Ekman, a body of water at a temperature of 13° would be cooled down during adiabatic change of volume by the following amounts, on being hauled up to the surface from the depths indicated:

3000	2500	2000	1500	1000	500 m.
0.49°	0.40°	0.31°	0.23°	0.15°	0.07°

If, on the other hand, the water-bottle is imagined as going from the surface downwards and not offering any resistance to compression, the temperature in the water-bottle will rise with the values given in the table, so that the temperature of the body of water insulated from the surroundings will be increased $^1/_2$° on going from the surface to a depth of 3000 m.

We may now consider more closely the distribution of temperature, which arises when a large body of liquid is cooled from the surface, restricting ourselves to the case where the salinity is quite constant in a vertical direction (thus applying also to freshwater lakes). According to the views prevailing hitherto, the whole body of liquid would then be in a state of indifferent equilibrium at the moment, when the temperature is constant from the surface to the bottom, and even a very slight increase in the density of the surface-water — produced by a slight increase in salinity or diminution of temperature — would then cause a sinking of the surface-water, which would continue until the uniform distribution of temperature was reestablished.

[1] In reality longer, as the conductivity of the bottom-material is probably considerably less than the conductivity which has been made the basis of the calculation of the value 40 cal.

Let us imagine now, that we have such an extensive mass of water with uniform temperature and salinity, for example, a layer of water 3000 m. thick in the Mediterranean with a temperature of 13°, and assume, that a small quantity of this is inclosed in a water-bottle, which is completely insulated and offers no resistance to compression, and the weight of which is inappreciable. When this water-bottle is let down from the surface, the water inclosed in it will be heated up and the difference of temperature between the water within and without will increase with the depth and become ca. $^1/_2$° at 3000 m.; the density of the water in the bottle is then less than that of the surrounding water-masses, and if the bottle were left to itself it would consequently rise upwards and the water within would become cooled during this movement, until it again reaches the surface and assumes the temperature of 13°.

If we imagine the water as inclosed in the bottle at a depth of 3000 m. and then hauled up, it will become cooled and constantly pass through warmer and consequently lighter masses of water; when it has arrived at the surface, its temperature has sunk to 12.5° and it would consequently, if left to itself, sink down until, under the increase of pressure, it was again warmed up to the same temperature as the surroundings, which would occur when the bottle had reached 3000 m. It follows from this, that the state of equilibrium is not at all indifferent at the moment, when the temperature is uniform throughout the whole layer of water, as a slight cooling of the surface does not cause the water from this to sink down through the whole mass of water. Thus, if we suppose, that the water in the bottle at the surface had a temperature of 12.85°, it will sink down but will stop at a depth of 1000 m., as it would be heated up to 13° by adiabatic compression during the movement from the surface to 1000 m. and thus meet water-masses here with the same density as it has.

If we suppose, on the other hand, that the temperature at the surface is 13° and increases downwards in accordance with the above table to 13.49° at 3000 m. and suppose the above experiment repeated, we see, that during the movement of the bottle downwards from the surface the temperature of the water in this will be increased by such an amount, that it always has the same temperature as the surrounding masses of water; on arrival at 3000 m. the temperature in the bottle is 13.49°, and during the opposite movement up towards the surface the temperature will again decrease by the same amount, from which we see, that the bottle with its contents will be in equilibrium at any and every point in the column of water. If, on the other hand, the temperature of the water in the bottle is somewhat lower than 13° (e. g. 12.90°), it will continue on its way downwards to be 0.1° lower than the water-masses it passes, and in 3000 m. it will have a temperature of 13.39°, so that the bottle has always passed through water-masses which had a less density than the water inside and it would consequently have carried out this movement downwards, had it been left to itself.

We see, therefore, that a column of water with uniform salinity is not in a state of indifferent equilibrium, when the temperature is uniform throughout; the equilibrium is only indifferent, when the temperature rises from the surface downwards with an amount which for the given depth is equal to the increase in temperature the surface water would have, when subjected to a pressure of the same amount as the hydrostatic pressure in the depth in question, under such conditions that it can neither receive nor give off heat to the surroundings. This increase of temperature, which can be calculated in any given case from Lord KELVIN's formula for the change of heat under adiabatic compression, is dependent not only on the pressure but also on the temperature and salinity of the water, and is represented graphically in fig. 13 (curve I) for Mediterranean water with a temperature of 13°. It is evident, further, that the vertical distribution of temperature in a layer of water, in which the temperature has been produced by the sinking down of cooled surface-water, must be determined in the same way, for it is only when the whole column of water has been cooled down so much, that the temperature downwards rises in accordance with the

values given by Lord KELVIN's formula, that an effective sinking of water-masses to the greatest depths can take place under a continued, slight cooling of the surface-water.

We have shown above, in discussing the vertical circulation in the Eastern Mediterranean, that the temperature in its bottom-layer is determined by masses of water coming from the northern border-regions, which after passing the threshold to the eastern basin must sink downwards to the greatest depths; on sinking down the temperature will gradually increase as the pressure, i. e. the depth, increases, and that this increase in temperature is very nearly equal to that calculated from Lord KELVIN's formula, is shown by the accompanying fig. 13, in which curve II represents the distribution of temperature at St. 160. At depths over 1500 m. this curve runs almost quite parallel with curve I, which shows the vertical distribution of temperature produced by descending water-masses, when the whole column of water is in indifferent equilibrium. As similar conditions occur everywhere in the eastern basin of the Mediterranean with regard to the distribution of temperature in the bottom-layer, we may conclude, that the temperature of the bottom-water is in reality determined by descending masses of water and that the temperature increase with the depth is due to the adiabatic rise of temperature produced during the descent of the water, whilst heating from the sea-bottom must be considered to be of little or no importance.

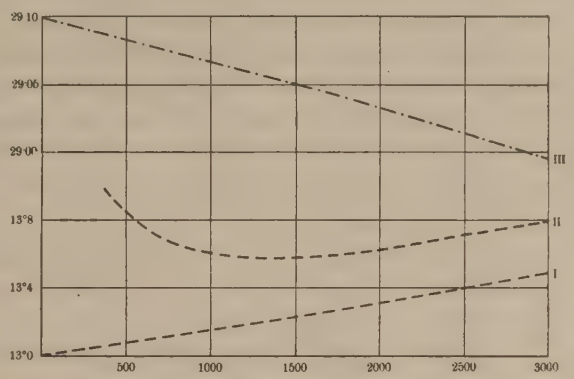

Fig. 13.

As the temperature increases appreciably with the depth, when a column of water is in indifferent equilibrium, it follows, that the limit of stability is not reached at the moment, when the density or σ_t is constant, but only when this decreases by the amount corresponding to the increase of temperature (in reality the density increases greatly downwards in consequence of the compression of the water, but it is evident, that the increase of density thus produced is of no importance for the conditions of equilibrium). The decrease in density corresponding to the above increase in temperature is shown below for a column of water, for which σ_0 is almost 31.00, when the value for $\frac{\Delta \sigma_t}{\Delta t}$ in the interval 13—14° is — 0.000212,

500	1000	1500	2000	2500	3000 m.
1.5	3.2	4.9	6.6	8.5	10.4×10^{-5}

so that σ_t, when made equal to 29.100 at the surface, will in the depths mentioned have the values:

29.085 29.068 29.051 29.034 29.015 28.996

These values are represented graphically in fig. 13 by curve III, which shows the distribution of density in a column of water, which is in a condition of indifferent equilibrium. At St. 160 as well as at all the other stations over great depths the values for σ_t show an intermediate maximum; nevertheless, the equilibrium is stable or as a rule very nearly indifferent; a descent of these intermediate, heavier masses of water, namely, will lead to their becoming warmer, which again leads to a reduction of the density, so that they cannot in reality reach down to the greatest depths with a density greater than the water-masses present there. A slight increase in density, for example from a slight increase of the salinity, will have the effect, on the other hand, that the intermediate masses of water will sink down, and the rapidity

with which this descent takes place, will depend not only on the density-gradient but also on the inner friction of the water.

The curves show, that the temperature distribution corresponding to the adiabatic changes of temperature only occurs in the bottom-layer and not in the intermediate layer, which naturally is due to the fact, that the salinity in the bottom-water is uniform, which is indeed a necessary presupposition for such a distribution of temperature. In the intermediate layer, on the other hand, the salinity increases upwards, for which reason the temperature also increases upwards under the indifferent condition of equilibrium, which, as is shown by the distribution of density at the different stations, is very nearly fulfilled in the lowermost part of the intermediate layer.

If the vertical circulation from the surface down through the intermediate layer was extensive, a similar distribution of tem perature would undoubtedly be produced in the latter as in the bottom-layer, and as such is not the case, the reason has probably to be sought for in a much less intensive vertical circulation in the intermediate layer, whilst the horizontal circulation is of much greater importance in consequence of the intermediate outflow through the Pantellaria Channel. The exchange of water, which takes place between the underside of the intermediate layer and the bottom-water, proceeds apparently by very slow mixing-processes, so that both the conduction of heat and diffusion are possibly of importance in the distribution of the temperature as well as of the absorbed gases.

As the adiabatic change of temperature is proportional to the heat expansion, which increases with the temperature, we see, that the increase of temperature with the depth must be considerably greater in the Mediterranean than in the deep water of the Atlantic under the same pressure (almost double as great), whilst it is probable, that the temperature gradient in the deep water of the Red Sea will have an even greater value. In spite of the fact, that this rise of temperature in the bottom-water of the Mediterranean is by no means inconsiderable, it has not been detected by earlier observers, nor indeed has the inversion of temperature in the sea as a whole been noticed until within quite recent years. Thus Helland-Hansen and Koefoed mention [1909, p. 58], that the temperature in the bottom-water of the Norwegian Sea is increased a little by conduction of heat from the sea-bottom, which however is not apparent from their vertical series of temperatures; on the other hand, they give a temperature observation taken by Nansen in the North Polar Basin, which really shows an increase of temperature in the deepest layers, and this is almost of the same amount as the adiabatic change of temperature corresponding to difference in pressure. The authors mentioned also explain this rise of temperature as due to a heating process from the sea-bottom, although it is noticeable through a layer of water of 900 m. in thickness.

In the Atlantic, where a possible rise of temperature in the bottom-water will only occur at very great depths, we have only recently learnt—probably owing to the extremely few measurements of temperature for the greatest depths — that it exists there also. Dr. Hjort [1910, p. 52] mentions, that a slight rise of temperature was detected at the greatest depths in the Atlantic during the Norwegian-Scottish Deep-sea Expedition in the summer of 1910 and Dr. Hjort explains it as arising from a conduction of heat from the sea-bottom or from a radium-effect. The temperature observations are not yet known to me, but I am inclined to believe, that the phenomenon here will also be referable to an adiabatic rise of temperature. Let us suppose, that the cold bottom-water with a uniform temperature of 2.5°, which flows southwards in the Northern Atlantic at, say, a depth of 3000 m., comes to a region where the depth is 4000 m. and suppose that its density is so great, that a portion moves downwards and fills this region, then it is obvious, that the descending masses of water will be heated up during their descent and their temperature raised by over 0.1°, whilst the temperature of the water-masses, which flow horizontally above, will remain unchanged at 2.5°.

In the case of inland lakes, a rise of temperature towards the bottom has repeatedly been observed

[Aufsess 1905, p. 105] and has been explained in various ways, sometimes as conduction of heat from the bottom, sometimes as coming from submarine springs and the like. From a critical examination of these temperature observations, however, Ule [1901, p. 150] comes to the conclusion, that this increase is frequently due to errors of observation, and where such are excluded, as in his own observations in Würmsee, the rise of temperature is of the same dimension as the error of observation.

As the temperature in the deep water of the freshwater lakes referred to does not differ much as a rule from 4° C., so that the heat-expansion of the water is slight at the temperatures dealt with, the adiabatic change of temperature during a descent of surface-water will be practically inappreciable, so that a noticeable rise of temperature towards the bottom cannot be produced in this way. At temperatures in the neighbourhood of 4° C., however, a temperature inversion is quite conceivable, without being due to heat from the bottom, as the variation of the density with the temperature is exceedingly slight, so that a cooling from the surface, when the temperature gradient is small, might possibly persist for years before it is completely equalized by vertical currents.

VII. Western basin of the Mediterranean.

Just as the hydrographical conditions in the eastern basin of the Mediterranean are determined by the meteorological conditions in conjunction with the inflow of fresher water-masses from the Black Sea and from the western basin, so also the hydrographical condition in the western basin is the result of an inflow from the west and from the east in conjunction with the prevailing meteorological factors, but whilst the inflow from the west comes in both cases from a surface-current of masses of water with a lower salinity than those present in the basin, there is a very essential difference in regard to the inflow from the east.

Although the outflow of surface-water from the Black Sea is relatively small quantitatively, yet owing to its salinity being only about one half of that in the Eastern Mediterranean, it is able to exercise a considerable influence on the salinity of the surface-layer especially in the Aegean Sea. In the western basin, on the other hand, the masses of water received from the east come, as already shown, from the salt, intermediate layer in the Ionian Sea, from which the outflow proceeds along the bottom over the threshold between Tunis and Sicily. From Sect. 6, Pl. V, it is seen, that these water-masses after passing the Pantellaria Channel have a salinity of 38.68 ‰ and a temperature of a little over 13.8°. As they are first met with at a depth of 150—200 m., it is evident, that the outflow must be restricted to the channel almost 400 m. deep between the western part of Adventure Bank and Cape Bon, so that the breadth of the undercurrent scarcely exceeds 15 miles.

As a continued movement westwards at the level, in which the salt water-masses occur, is for the most part hindered by the bank, which extends from Bizerta out towards the Skerki Bank, they are forced to move further in a northerly direction outside the latter, the indication of a deeper course (Skerki Channel) to the south of the bank being probably of too slight a depth to be of any appreciable importance for the transport of the outflowing masses of salt water. It is seen, at any rate, from St. 134, which lies due west of the Skerki Channel, that the salinity here is not higher than in the remaining part of Sect. 8 from Sardinia to Tunis, and that the salt water-masses consequently cannot flow through this channel, but must pass north round the Bank, and the Tyrrhenian Sea thus comes to serve as the connecting link between the eastern basin and the Balearic Sea.

1. The vertical distribution of temperature and salinity.

a. The Tyrrhenian Sea.

We may take St. 129 (fig. 14) as typical for the Tyrrhenian Sea, partly because it represents the greatest depth we have investigated, and partly because it lies about in the middle of the basin, so that local irregularities may be considered as reduced to the least possible. From fig. 14a we see, that the temperature decreases fairly rapidly from the surface, and that the temperature gradient is specially great between 25 and 35 m., after which it becomes less until at ca. 100 m. (fig. 14) we meet with a distinct temperature minimum of 13.75°, followed by just as distinct a maximum of about 14° in 200 m., after which the temperature decreases relatively slowly and again has a minimum at about 2000 m., then rising slowly downwards.

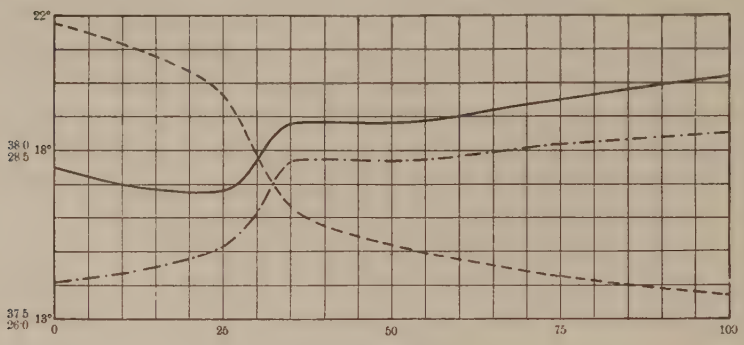

Fig. 14 a. (St. 129).

Comparing this temperature curve with the two typical curves for the Levant and the Ionian Sea (figs. 8 and 11) we find, that it is essentially different from these by the presence of the intermediate minimum and maximum at a depth of respectively 100 and 200 m. (in the northern part of the Ionian Sea,

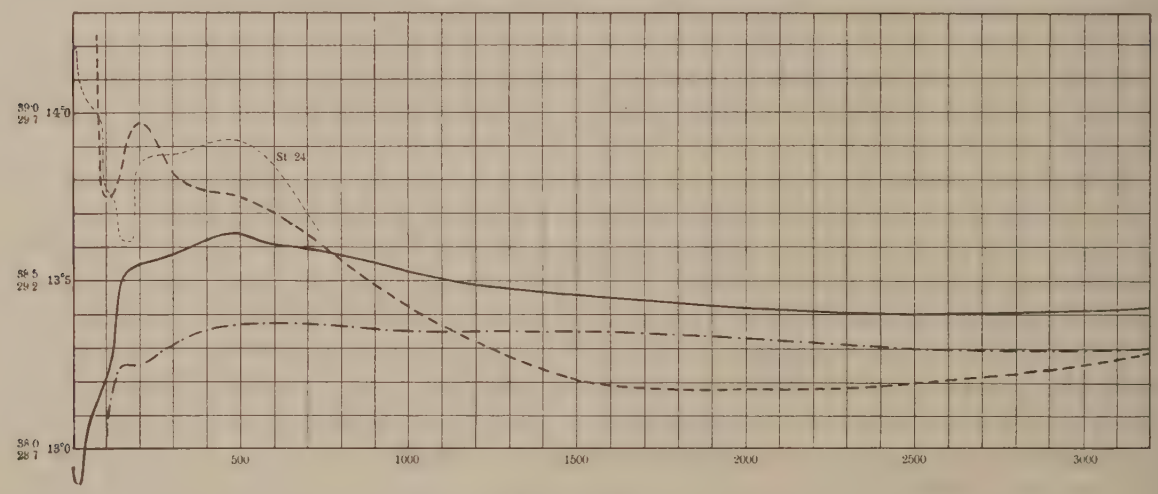

Fig. 14. (St. 129).

however, there is a similar though less marked distribution of temperature, see St. 187, fig. 12), and we also see, that the temperature in the Tyrrhenian Sea decreases down to ca. 800 m. much more slowly than in the eastern basin, as also that the temperature minimum occurring in deep water, which in the latter was found already at about 1200—1300 m., is first met with at about 2000 m. in the Tyrrhenian Sea. Just as in the eastern basin, a layer of water over 1000 m. thick, in which the temperature is very nearly uniform, is found about the depth at which the temperature gradient changes sign, and below this layer the course of the different temperature curves is quite analogous, so that the increase of temperature with the depth seems to be very nearly the same.

With regard to the absolute value of the temperature, this is somewhat lower at all depths in the Tyrrhenian Sea than in the eastern basin, but the difference is small about 600 m., less than 0.1°; at depths of 2000 m. and more, where the curves of temperature are almost parallel, we see on the other hand, that the temperature is for any depth very nearly 0.5° lower in the Tyrrhenian Sea than in the Levant and 0.4° lower than in the Ionian Sea.

The vertical distribution of the salinity in the Tyrrhenian Sea is analogous with what we have found in the Ionian Sea (cf. fig. 11); there is a surface-layer with low salinity (in both cases a minimum at 25 m.), then a fairly considerable increase with the depth to a maximum, after which it decreases slowly and becomes constant in the bottom-layer. We may remark, however, that evaporation has had much less influence on the surface at St. 129, this being only a little higher than the minimum at 25 m., and that the maximum, which at St. 144 occurred between 200 and 300 m., is first met with at 500 m. at St. 129, as also, finally, that the salinity decreases downwards very slowly and only becomes to some extent uniform at about 2000 m., which occurred in the Ionian Sea a little below 1000 m.

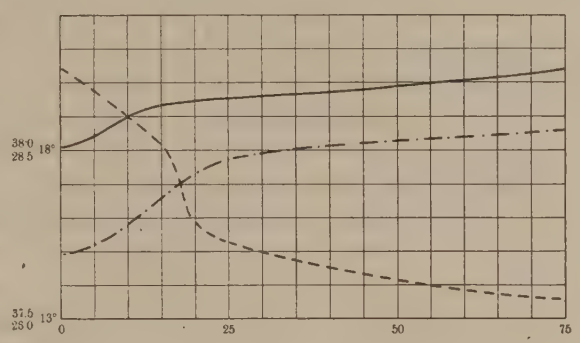

Fig. 15 a. (St. 132).

In the bottom-water the salinity is 0.20—0.25 ‰ lower in the Tyrrhenian Sea than in the Eastern Mediterranean, but about 500 m. the difference is only a little over 0.1 ‰, and the maximum at St. 129 is 38.64 ‰, which is only 0.04 ‰ lower than the salinity of the water-masses, which have just passed out from the eastern basin through the Pantellaria Channel into the Western Mediterranean and are met with to the south-west of Sicily at St. 138 and 139. With regard, lastly, to the density, this as in the Eastern Mediterranean is very nearly constant from the depth at which the maximum of the salinity occurs, but yet decreases very slightly with the depth.

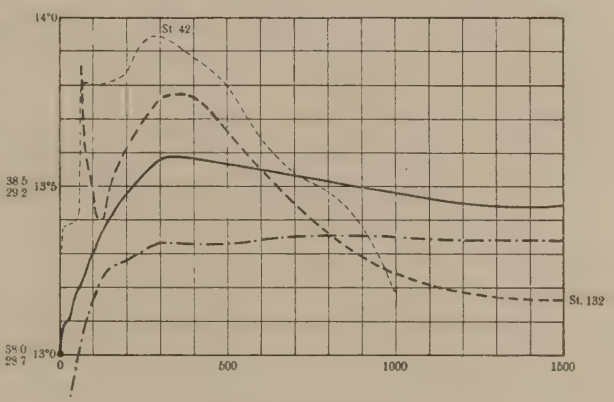

Fig. 15. (St. 132).

A station (24) was investigated in January 1909 in the neighbourhood of St. 129, which shows, that the vertical distribution of temperature and salinity is at this time of year in all essentials the same as that found in the summer. The temperature observations, which seem somewhat unreliable for the deepest parts and are represented for the upper layers by the faint, dotted curve in fig. 14, show, however, that the intermediate minimum and maximum of the temperature lie somewhat deeper in winter, as the former is found at 150—175 m., whilst the maximum lies at a depth of 400—500 m., where the temperature is ca. 0.15° higher than in the same depth at St. 129; on the other hand, the distribution of the salinity is almost quite unchanged, though the intermediate maximum seems to be slightly lower in the summer. Towards the boundaries of the Tyrrhenian Sea the above typical conditions change somewhat, but we still have fairly analogous conditions towards the Sardinia Channel (St. 132, fig. 15), though the intermediate maximum values are somewhat lower both for the temperature and the salinity, and further the maximum temperature is lower in summer than in winter (see St. 42 in fig. 15).

b. The Balearic Sea and adjacent waters.

In the central part of the Balearic Sea the vertical distribution of temperature is very much the same as in the Tyrrhenian Sea, so far as the upper layers are concerned (St. 116, fig. 16); there is a minimum of temperature at about 150 m. and under this a maximum at almost 300 m., after which the temperature decreases, but already reaches its lowest value, ca. 12.85°, at a depth of ca. 1000 m., whereas in the Tyrrhenian Sea this was first met with at nearly double the depth, where the temperature was ca. 13.2°; from the minimum at ca. 1000 m. the temperature again rises slowly and to some extent proportionally with the depth and is ca. 13.0° at 2000 m., so that the difference of temperature between the Tyrrhenian and the Balearic Sea at depths of 2000 m. or more is about 0.15°. The salinity is almost quite constant at 38.35—38.38 ‰ from the bottom to ca. 1000 m., from which it increases slowly upwards to a maximum of 38.46 ‰, which is almost at the same place as the maximum of temperature; from there the salinity again decreases up towards the surface.

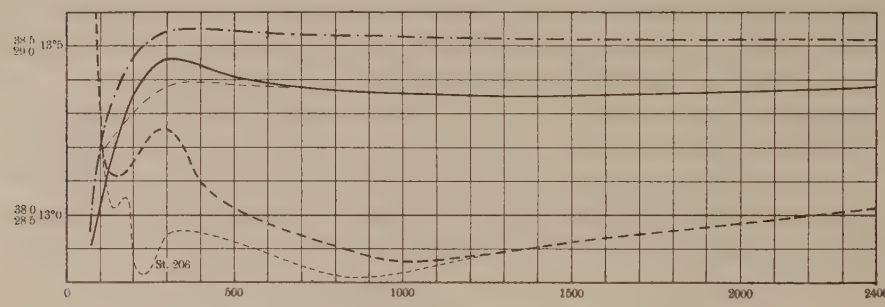

Fig. 16. (St. 116 and — the faint curves — St. 206).

Thus, whilst the difference between the maximum values at ca. 300 m. and the lowest values in the lower layers (for the temperature the minimum at ca. 1000 m., for the salinity the constant value from 1000 m. and downwards) only amounts to respectively 0.4° and 0.1 ‰ in the central part of the Balearic Sea — values considerably less than the corresponding values in the Tyrrhenian Sea — the conditions are somewhat different in the north-eastern part of the western basin of the Mediterranean, the Ligurian Sea. We see from St. 122 (fig. 17), that the intermediate maximum here both for the temperature and salinity is somewhat more marked and the absolute values somewhat (ca. 0.3° and 0.1 ‰) higher than at St. 116. During the winter cruise also, almost the same maxima were found for the temperature and salinity as in July 1910, but the maxima were first met with at a considerably greater depth, namely about 450 m.

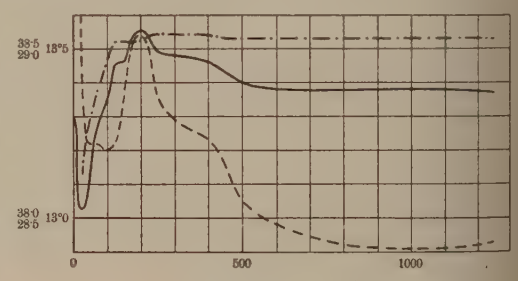

Fig. 17. (St. 122).

In the north-western part of the basin, at St. 209 north-west of the Balearic Isles, we again find conditions which differ considerably; the intermediate maximum of temperature has disappeared, with the result that the minimum, which we find at depths about 1000 m. in the other part of the western basin, already occurs between 200 and 300 m. where the temperature is only a little over 12.7° and increases fairly evenly downwards. In agreement with the fact, that the intermediate maximum of temperature is closely bound to a maximum in salinity, we do not find any indication either of the latter at St. 209; close to the coast off Barcelona, however, there is again a faint maximum at 300—400 m., so that a considerable increase of temperature is found at depths from 50—300 m. in towards the coast.

A station (206) was investigated 2 months later at very nearly the same place in the central part of the Balearic Sea as St. 116 and the results are shown in fig. 16 in the faint curves. We see from

these, that the temperature minimum below the surface has moved about 100 m. downwards, and the subsequent maximum has a value below 13°, thus 0.3° lower than at the end of June; an appreciable reduction in temperature has even taken place down to depths of 1000 m. Of the intermediate maximum of salinity there is only a slight indication at 400 m. and we thus see, that considerable changes have taken place in the interval in the intermediate layer of water down to 1000 m., and that the warmer and salter masses of water have been replaced by others with a much lower temperature and salinity.

Towards the south-western part of the Balearic Sea the intermediate maxima become less marked, but for the temperature they could still be detected in the Alboran Sea, in the section from Cape de Gata to Oran. A comparison of the curves for the temperature and salinity at the stations 53, 107 and 223 investigated respectively in February 1909 and in June and September 1910 at almost the same place, shows that the maximum lies nearest the surface in June and deepest in February; it is extremely little marked in September and most distinct in February, when the maximum is 0.15° higher than the minimum above; in February also the maximum of the salinity is more marked than in summer, at which time it is so little conspicuous, that it only has any importance from occurring along with the maximum in temperature. For the rest, the conditions at depths of 400 m. and more are almost quite the same at the 3 stations, from which we may conclude, that extremely small changes occur here in the course of the year.

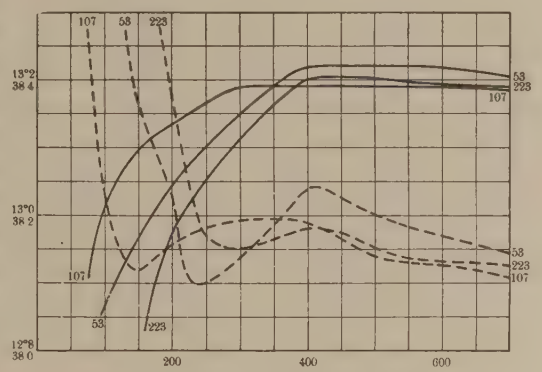

Fig. 18. (Sts. 53, 107 and 223).

2. The horizontal distribution of temperature and salinity and the horizontal circulation in the Western Mediterranean.

a. The Tyrrhenian Sea.

The horizontal distribution of temperature and salinity in the Tyrrhenian Sea will be most readily understood from a consideration of the various vertical sections, and we may at the same time consider the horizontal movements in this basin. Of special interest are the three sections 6, 7 and 8, Pl. V, respectively from Tunis to Sicily, from Sicily to Sardinia and from the last to Tunis, as they are thus approximately vertical sections across the connections between the eastern basin of the Mediterranean and the Tyrrhenian Sea and between the latter and the Balearic Sea, and may thus form the basis for an estimation of the exchange of water, which takes place between these.

Section 8 A between Sardinia and Tunis shows, that there is a very considerable difference in the salinity from north to south, as the salinity in the southern part is about 1 ‰ lower down to about 100 m. and that the fresher masses of water have a somewhat higher temperature than the salter towards Sardinia. The boundary between the fresh masses of water in the southern and the salter in the northern part has a fairly irregular form, as a tongue of rather high salinity extends towards the south at a depth of about 25 m. (the 37.5 isohaline extends almost to St. 134 at a depth of 25 m.), whilst the fresher masses of water spread further north in about 50 m. than in 25 m.; at the former depth, also, at St. 134, we find the lowest salinity occurring anywhere in this section, namely 36.87 ‰, whilst the salinity in the southern part of the section is elsewhere somewhat over 37 ‰.

The water-masses, which occur in the southern part of the section, consist for the most part, as the low salinity indicates, of Atlantic water and we see, that the salinity of the latter has scarcely increased by 1 ‰ from mixing with the Mediterranean water and from evaporation on the way from Gibraltar to the Sardinia Straits; at depths about 100 m. the salinity begins to increase appreciably and towards 200 m. the influence of the Atlantic water is not noticeable. Nor is any great influence of the Atlantic water appreciable in the northern part of Sect. 8 A, the salinity here in the uppermost layer — a little over 38 ‰ — being almost the same as that found over the greater part of the Tyrrhenian Sea.

The Skerki Channel is probably not sufficient for the transport of the fresher masses of water towards the east which pass Sect. 8, and a portion must therefore move northwards round the Skerki Bank, which is probably the reason why the 37.5 and 37.75 isohalines east of the Bank at St. 138 lie somewhat nearer the surface than in both the southern and northern part of Sect. 6 A; in this both at St. 137 and St. 138 we find a layer of 10—20 m. in thickness with a somewhat higher salinity about 30 m. below the surface, probably produced by a similar tongue of salter water as that found at 25 m. in Sect. 8 A, which has been carried away by the east-going, fresher masses of water and now appears as an isolated patch in these. Whilst we had the highest temperature in the southern part in Sect. 8 A, the case is reversed in Sect. 6 A, where between 150 and 200 m. there is a distinct minimum, which arises from the fact, that the salter masses of water from the eastern basin, which have a fairly high temperature, extend considerably nearer to the surface in the northern part of the section than in the southern part.

We have already noticed above, that the salt masses of water from the eastern basin, which we find in the bottom-layer in Sect. 6, where the salinity is uniform and equal to 38.68 ‰, must move northwards round the Skerki Bank and we now see also from Sect. 8, that the salinity in the intermediate layer, where it has its maximum, is not any higher at St. 134, which lies just outside the Skerki Channel, than in the remaining part of the section. As the maximum of the salinity in the intermediate layer in Sect. 8 is quite constant from north to south and equal to 38.58 ‰, it seems reasonable to conclude, that the saltest masses of water do not move in a westerly direction north round the Skerki Bank, as we can with difficulty imagine such a great reduction of the salinity in so extensive a layer over such a short distance, and we also see from Sect. 7, that they must for the most part pass through this section and then into the Tyrrhenian Sea.

It is not only in the intermediate layer, however, that the Tyrrhenian Sea receives new masses of water through Sect. 7, there is also an inflow at the surface. From Sect. 10 A we see, that a fairly extensive layer with somewhat low salinity occurs in the southernmost part of the Tyrrhenian Sea; at St. 194 north-west of Messina the salinity has its minimum 37.59 ‰ in 35 m., and as this value is considerably lower than in the remaining part of the basin, it must evidently have come from an inflow into the Tyrrhenian Sea of a portion of the fresher masses of water, which are found in the eastern part of Sect. 7. We see, therefore, that the whole quantity of water of Atlantic origin, which passes through the Sardinia Channel, does not go further into the Eastern Mediterranean, but that a part of it flows into the Tyrrhenian Sea. We see, further, that this surface current of fresher masses of water keeps along the coast of Sicily, and the reason for this is certainly to be sought for in the deflecting influence of the earth's rotation. Later, presumably, it turns towards the north along the coast of Italy and we may also notice (Sect. 11 A), that we still find near the coast in the latitude of Naples a somewhat lower salinity in the surface-layer down to over 100 m. than in the middle of the basin.

That the low salinity in the south-eastern part of the Tyrrhenian Sea does not come from an inflow of the relatively fresh surface-layer from the Adriatic through the Straits of Messina, appears from Sect. 10 A with all the clearness one could wish for. In this section, in addition to St. 192 between Messina and Reggio immediately south of the Straits of Messina, we also have St. 189 which lies in the Ionian

Sea to the south of Calabria. Although the distance between the two stations 192 and 194 is only 55 km., the salinity down to a depth of 200 m. is about 0.5 ‰ lower at St. 194 than to the south of the Straits of Messina, a difference which is much larger than that occurring from the south-eastern to the northernmost part of the Tyrrhenian Sea. There seems no doubt, therefore, that there is no noteworthy exchange of water between St. 192 and St. 194, and the Straits of Messina are hardly of any great importance either in the exchange of water between the Tyrrhenian and Ionian Seas. It is not surprising, therefore, that the strong currents occurring in the Straits are stated by the later authors to have rather the character of tidal currents with variable direction, arising from the fact, that high water in the Tyrrhenian Sea occurs at the same time as low water in the Ionian Sea and conversely, so that there can be no talk of any effective transport of water through the Straits.

It may be remarked, that the often fanciful reports regarding the currents in the Straits of Messina give an exaggerated picture of what actually occurs. When it is said, for example, that masses of water rise up from the deeper layers and that powerful vertical movements occur in the upper layers, we must take the "deeper layers" in a restricted sense as applying to depths hardly more than 100 m. We find namely quite the same salinity in 100 m. at St. 189 as at St. 192, and if any ascent of deeper masses of water actually took place, we should certainly notice it at St. 192, that is, if carried out on a large scale. We see further, that it is only in the uppermost layer above 25 m. that the temperature at St. 192 is appreciably different from the neighbouring St. 189; below 25 m. the decrease of temperature with the depth is about the same on both stations.

As the conditions at St. 192 are thus on the whole not essentially different from those at the neighbouring stations in the Ionian Sea, we are able to draw the conclusion that if vertical movements of any importance really do take place in the Straits of Messina, they must be of a local nature and restricted to the narrowest and shallowest part of the Straits.

Whilst the salinity of the saltest, intermediate masses of water decreases from 38.68 ‰ immediately west of Sicily to 38.58 ‰ at the south-east point of Sardinia, we see, that it is almost unchanged from the former place to the south-eastern part of the Tyrrhenian Sea, where in Sect 10 we find an intermediate maximum at 400—600 m. with values which vary extremely little in a horizontal direction and all lie between 38.64 and 38.68 ‰. In Sect. 11 from Naples to the south-east point of Sardinia we likewise find a maximum of 38.64 ‰ about 400 m. in the eastern part, whilst the maximum at Sardinia is 38.60 ‰, thus decreasing somewhat towards the west, but almost unchanged from the middle of July to the end of August. In Sect. 9 from Tunis to Genoa we also find the maximum value 38.64 ‰ in the centre of the basin about 400—500 m., whilst it is 38.57—38.58 ‰ in the southern part of the section and lies at a depth of 300 m.; the maximum also decreases towards the north and is 38.53 ‰ west of Elba.

Considering now the circulation in the intermediate layer, where the maximum of salinity occurs, it appears from the above-described distribution of the salinity, that these masses of water from the west point of Sicily first spread out over the south-eastern part of the Tyrrhenian Sea and from there to the central part, leaving this basin in slightly mixed form. To judge from the salinity, by far the greater part of the outflow takes place through the Sardinia Channel, but water from the intermediate layer also flows out between Elba and Corsica into the Ligurian Sea, as is already evident from Sect 9, which shows, that a layer of water with a salinity over 38.5 ‰ extends right up into the Bay of Genoa, a fact we shall discuss later. Excluding meanwhile the outflow towards the north, we may characterize the movement of the intermediate, salt masses of water which enter the Tyrrhenian Sea west of Sicily, as a cyclonic rotation, after which they leave this basin through the Strait south of Sardinia.

The investigations made in the winter of 1909 (Sect. 12) agree excellently well with those discussed above for the summer of 1910. The salinity in the intermediate layer in the central part is on the whole

very slightly — up to 0.04 ‰ — higher, a difference which becomes about 0.1 ‰ in the northernmost part and likewise to the south of Sardinia, which indicates, in conjunction with what we have already seen, that the outflow from the Eastern Mediterranean is most intense in the autumn. Even if the slightly higher value is due to a higher salinity in the masses of water flowing out of the eastern basin in autumn, yet we see, that the variation in the salinity of these is fairly small in the course of the year.

As indicated in discussing the vertical distribution of temperature and salinity, the intermediate layer in the Tyrrhenian Sea has a much greater thickness than in any other part of the Mediterranean, and the various vertical sections also show, that the temperature and salinity continue to decrease down to about 2000 m.; it is only at this depth, where the temperature has a minimum and the salinity becomes constant, that we can consider that the bottom-water begins. At such great depths we have only a few observations and these do not give a sufficient basis for the discussion of the horizontal distribution; yet both the temperature and salinity seem to be almost constant in a horizontal direction. With regard to the salinity the value in the bottom-water is a little over 38.40 ‰ or about 0.05 ‰ higher than in the bottom-water of the Balearic Sea, just as the temperature is 0.1°—0.2° higher than at the same depth in the latter. This shows, that the bottom-water from the Balearic Sea does not extend, in unchanged condition, into the Tyrrhenian Sea, but that its temperature and salinity are somewhat increased by mixing with the lowermost part of the intermediate layer.

All the temperature observations made in the Tyrrhenian Sea in the summer time show, that there is everywhere a minimum at a depth, which increases somewhat from south to north but yet seems to lie as a rule between 100 and 200 m. This minimum is also found at some of the stations for the winter of 1909, whilst at others, e. g. St. 30, there is a steady decrease in temperature from the intermediate maximum to the surface, where the lowest temperature occurs. The only possible explanation of the existence of this intermediate minimum is, that it comes from the cooling which has taken place in the preceding winter. The reason why it is absent at some of the winter stations is, that the surface-layer warmed up in the intervening summer was already so much cooled down, at the time when the observations were made, that the cooling of the winter has reached down to the layer cooled down in the preceding winter, and we can also see, that at the stations where the intermediate minimum has disappeared, the surface temperature is considerably lower and the cooling of the surface consequently more advanced than at the other stations.

Since now this minimum of temperature is succeeded by a marked maximum, from which the temperature decreases to some extent evenly with increasing depth down to about 2000 m., both in summer and winter, we may conclude, that the cooling from the surface and the consequent vertical circulation does not extend deeper down than to the temperature minimum, so that the influence of the vertical circulation is in general scarcely felt at depths more than 200 m. The conclusion drawn from SEMMOLA's temperature observations in the Bay of Naples (see p. 92), that a homothermal condition occurs in the Tyrrhenian Sea in winter, must therefore be considered erroneous. Further, SEMMOLA only found a constant temperature to 180 m., which is not in opposition to the actual value for the extension of the vertical circulation, and it is also probable, that it extends somewhat deeper close to the coasts than in the middle of the basin, just as the cooling may reach down to greater depths in the northern part; thus at St. 126 the minimum of temperature seems to lie somewhat below 200 m.

The reason why the vertical circulation proceeding from the surface extends such a little way down, is due naturally to the great difference in the salinity between the surface-layer and the intermediate layer. In the latter the maximum of the salinity over the greater part of the Tyrrhenian Sea is above 38.6 ‰, whilst at the surface it is about 38.0 ‰. As the cooling of the surface-water gradually advances in winter and the uppermost layers become mixed, the salinity at the surface will rise, but it will scarcely

become higher than 38.3 ‰, as we find this salinity as a rule along with the intermediate minimum of temperature, and the cooling is not sufficiently intense to give the masses of water with such a low salinity a density greater than that in the intermediate, salt layer.

The conditions in the Tyrrhenian Sea are thus to a great extent analogous to those in the Ionian Sea; the less saline surface-layer shelters the intermediate layer against cooling and thus prevents a direct sinking down to the bottom-water. This in conjunction with the fact, that the deep water in the Sardinia Channel, through which an inflow of bottom-water can take place from the Balearic Sea, only has a small breadth, is undoubtedly the reason why the intermediate layer attains to such great dimensions in the Tyrrhenian Sea; as the bottom-water is only renewed slowly, a mixing takes place between this and the intermediate masses of water during their circulation, which mixing possibly proceeds so slowly, that the conduction of heat may also have some influence on the vertical distribution of the temperature.

b. The Balearic Sea and adjacent waters.

We shall now consider the horizontal distribution of temperature and salinity in the Balearic Sea and on the basis of this discuss the horizontal movements which make take place in the different layers of water. Considering first of all the intermediate layers, we see from Sect. 13, Pl. V, that in the winter of 1909 there is a maximum in the salinity of over 38.6 ‰ from 300—600 m. over the whole of the Sardinia Channel, yet with somewhat lower values in the southernmost part than in the northern. The salinity however decreases somewhat greatly towards the west, and the maximum at St. 46 is 38.48 ‰ in 450 m., which indicates that the main mass of the salter water coming from the intermediate layer in the Tyrrhenian Sea, does not move at once in a westerly direction after entering the Balearic Sea through the Sardinia Channel.

A consideration of Sect. 14, Pl. VII, which extends from Algiers to Genoa and was taken near the end of June 1910, shows that the thickness of the intermediate, salter layer with a salinity over 38.40 ‰ is barely 200 m. at Algiers, but increases towards the north and is ca. 600 m. at St. 118, lying to the west of the Straits of Bonifaccio, where however the highest salinity 38.49 ‰ also occurs. As this station lies at a greater distance from the south point of Sardinia than St. 116, but on the other hand nearer the east side of the Balearic Sea than the more southerly stations in the section, it is evident, that the main portion of the intermediate masses of water bend in a northerly direction along the west coast of Sardinia, the Straits of Bonifaccio being naturally of no account in this regard, as the depth there is less than 100 m.

The intermediate maximum for the temperature, which is closely bound to the salinity maximum, leads to quite the same result. At St. 45 and St. 46 the temperature maximum is in 300 m., but decreases 0.45° from 45 to 46, and in Sect. 14 where the temperature has its maximum at about 250 m., the maximum rises from 13.23° at Algiers to 13.57° at St. 118, a value that is only ca. 0.2° lower than what we find in the middle of July at St. 132 south-east of Sardinia as the maximum in the intermediate layer.

From St. 118 the dimensions of the intermediate layer with a salinity over 38.40 ‰ again decrease towards the north and north-west of Corsica scarcely exceed 200 m.; it is doubtful, however, whether it exists at all, but as we have no stations which expressly show this, the 38.4 ‰ isohaline is continued to the northernmost part of the section in the Ligurian Sea, where the salinity again increases and is even higher than at St. 118, the highest value here being 38.55 ‰. A corresponding variation is also found in the maximum temperature; at St. 120 this is only 13.12° but increases northwards to a little over 13.5°.

The reduction in the extent of the intermediate layer from St. 118 to 120 does not arise from an increase in the distance from the east side of the basin, since St. 120 lies nearer the latter, and this con-

dition may therefore indicate, that the intermediate masses of water do not enter the Ligurian Sea to the west of Corsica, or at least only to a small extent; the main body when west of Corsica bends in a north-westerly or westerly direction into Toulon Bay. We shall see below, however, that there is some ground for believing, that the intermediate layer here to the north-west of Corsica completely disappears in the course of the winter and that the normal condition of the summer is just beginning to show itself, namely, in an increase in the thickness of the intermediate layer.

It appeared already from the observations made during the winter cruise, that the intermediate maximum was more marked in the northernmost part of the Ligurian Sea than in the Balearic Sea, which seemed to me quite inexplicable, as the depth-chart at my disposal showed, that the depths between the northern part of Corsica and Italy were everywhere less than 200 m. This depth was too small to permit of the intermediate layer of the Tyrrhenian Sea coming into connection this way with the Ligurian Sea. During the summer cruise, therefore, a series of soundings was made between Corsica and Capraia, and it then proved, as was also found from more detailed charts, that the Straits had in reality depths of ca. 400 m., and it is thus evident, that the intermediate layer nearest the Ligurian coast has arrived here through the northern exit of the Tyrrhenian Sea. This we have already seen from Sect. 9, which shows quite the same conditions in the intermediate layer in the Ligurian Sea as in the northernmost part of the Tyrrhenian at St. 126. From Sect. 9 we see, that the intermediate masses of water in the Ligurian Sea have their greatest extent in the northern part, and they must consequently keep to the eastern side until they are forced in a westerly direction by the coast. This movement is quite analagous with what we have described for the Balearic Sea and is undoubtedly due to the influence of the earth's rotation.

From Sect. 15, Pl. VII, which extends from the south point of Sardinia over the Balearic Isles to Barcelona, we see how both the temperature and salinity of the intermediate layer decrease towards the west; the maximum salinity decreases from 38.60 ‰ at St. 202 to St. 206, where there is an indication of a maximum of 38.39 ‰ in 400 m., but the variation of the salinity with the depth is here (see fig. 16, p. 150) almost inappreciable below 300 m., just as the variation in the temperature is also slight and amounts to ca. 0.1°. North-west of the Balearic Isles there is no trace of the salinity maximum, and in 300—400 m., where it usually appears, the values are even somewhat lower than in the deeper layers and, in place of the usual maximum of temperature, we find here at St. 209 a minimum of 12.73° in 300 m. Near to the coast off Barcelona an intermediate layer of about 300 m. in thickness again appears with a salinity over 38.40 ‰ in connection with a somewhat higher temperature.

In the Catalonian Sea from St. 209 to St. 215 (Sect. 16) the conditions are very uniform at depths of over 200 m.; here there is no maximum for the salinity, and the temperature from the above depth to ca. 1000 m. is below 12.8°, which is somewhat lower than everywhere else in the part of the Balearic Sea investigated. At St. 215 there is an unusual distribution of temperature in the uppermost layers: at 150 m. there is a slight maximum without a corresponding maximum for the salinity, but south of Iviza the distribution of temperature normal for the Balearic Sea is again found with a minimum at 150—200 m. and a maximum about 300 m. and in the southern part off Algiers a distinct maximum of salinity again appears with values a little over 38.40 ‰.

Further to the west, in the Alboran Sea, we find in the main the same conditions in the intermediate layer as in the Balearic Sea; in the sections 17—19 (Pl. VIII) from Cape de Gata to the coast of Algiers west of Oran we find everywhere an intermediate maximum in the temperature, though the value of this is not much (ca. 0.1°) higher than that of the temperature minimum lying above. The maximum temperature in winter (Sect. 17, 1909) is a little over 13°, whilst in June and September 1910 it is a little under 13°, and is met with in winter between 400 and 500 m. in summer somewhat higher up in the southern, but still deeper in the northern part. The intermediate maximum for the salinity as for the temperature

is somewhat higher in February 1909 than in the summer of 1910; at the former period there is a considerable layer of water in the southern part of the section with a salinity over 38.40 ‰, whilst the maximum in 1910 is 38.39—38.40 ‰.

Special conditions seem to prevail in the northern part at the Spanish coast, where in June there is a layer from 200—500 m. with a temperature under 12.9° and the temperature on the whole seems to be somewhat lower than in the other part of the section. The salinity also shows some divergence, there being no indication of a maximum in June, whilst in the winter of 1909 it is much less marked than in the southern part. Towards the Straits of Gibraltar the intermediate maxima in the temperature (a little over 13°) can still be detected at the winter stations and in part also the salinity maximum in 400—500 m., and a temperature minimum occurs in 200—250 m., whilst off Tarifa a temperature decreasing from the surface downwards is found and thereafter a bottom-layer with uniform temperature and salinity. A similar distribution to that just described was found in June 1910 just inside Gibraltar, whilst in September the temperature slowly decreased to the bottom, where 12.77° was found at 700 m. or about 0.2° lower than the values observed in winter at the same depth.[1]

From what has been shown above with regard to the occurrence of the intermediate layer with maximum temperature and salinity, it appears that a portion of this comes from the northern part of the Tyrrhenian Sea, from which it flows out into the Ligurian Sea to the east of Corsica, and that the main body of water keeps to the east side of this, to bend in the northern part in a westerly direction. The value of the maximum salinity remains almost unchanged from the latitude of Elba to the Gulf of Genoa. The main body of the outflowing, intermediate masses of water from the Tyrrhenian Sea leaves this however through the Sardinia Channel and then keeps mainly to the north side of the latter, after which it for the most part bends in a northerly direction along the west coast of Sardinia and Corsica, from which the value of the maximum salinity decreases out towards the middle of the basin. These north-going masses of water do not seem to reach the Ligurian Sea, but probably bend in a north-westerly and westerly direction over towards the French coast, where they unite with the water which has passed through the Ligurian Sea, and in the north-western part of the Balearic Sea the direction of movement is gradually changed to the south-west and south.

The velocity of this movement must be considered to be greatest in the outer cant of the basin, as we see that the intermediate masses of water at the end of August have reached along the coast down to Sect. 15 off Barcelona, whilst they are not yet found at a somewhat greater distance from land at St. 209. The movement probably continues during the autumn in a south-westerly direction along the Spanish coast, which means, that new intermediate masses of water are carried down into the Alboran Sea and towards Gibraltar.

As we have seen from fig. 16, considerable changes have occurred in the intermediate layer of water east of the Balearic Isles in the course of July and August 1910. In discussing the vertical circulation in the Western Mediterranean we shall see, that the whole of the intermediate layer in the northern part probably disappears in the course of the winter as the result of the mixing process following upon the cooling, and that new intermediate masses of water are then added in the course of the summer and autumn. If we assume provisionally, that such a uniform condition without intermediate maximum has prevailed in the northern part of the Balearic Sea in the spring of 1910, the water-masses present here — if they do not sink down to greater depths — will move in a southerly direction with the horizontal current discussed above, and it seems to me probable, that the disappearance of the inter-

[1] I may remark here, that the depths in the Alboran Sea in the neighbourhood of the Straits of Gibraltar are probably not so great as is marked on the charts; thus, the depth at St. 228 was 720 m., whilst the chart gave it as being over 1000 m. As there is usually a strong surface-current running here, it is evident that soundings will give uncertain results, as the sheer of the lead-line will be much greater than apparent from the surface (cf. the "Shearwater's" sounding of 1070 m. at the same place where Capt. Smyth indicates to have taken a water-sample from 1225 m.).

mediate layer from St. 116 is due to its being driven out by more northerly masses, which have moved down to the east of Minorca, whilst the intermediate layer found in June may have moved in an easterly or north-easterly direction.

Taken on the whole the intermediate layer of water in the western basin seems to be considerably more developed during the winter than during the summer, and the explanation is, probably, that it partly disappears from cooling and mixing with the surface-layer in the latter part of the winter, whilst a new inflow from the eastern basin in the course of the summer and autumn leads to an increase, which persists until the cooling from the surface and the consequent vertical circulation begins in winter to reduce the intermediate layer. As already indicated, the greater volume in winter is perhaps also due in part to the fact, that the outflow from the eastern basin has an annual period with a maximum in the autumn, when the concentration of the surface-water in the eastern basin is most advanced. In this case we may also assume, therefore, that the velocity of the intermediate current is greatest at this time of year.

The movement of the currents seem to be more or less analogous in the Tyrrhenian and Balearic Seas, namely, a cyclonic rotation during which the intermediate masses of water keep mainly to the right side of the region, due probably to the influence of the earth's rotation. On the south side of the Tyrrhenian Sea the cyclonic movement is interrupted, the water-masses instead of bending towards the east leaving the basin through the Sardinia Channel. Similarly, the cyclonic rotation must be altered in part on the south side of the Balearic Sea, as a portion at any rate of the intermediate masses of water go towards the west into the Alboran Sea and leave this through the Straits of Gibraltar. The lower salinity we find in the northern part of the Alboran Sea, in the section from Cape de Gata to Oran, must probably be due to the fact, that these water-masses still bear considerable signs of the influence of the cooled and mixed water in the northern part of the Balearic Sea.

Our investigations are not sufficient, however, to settle the question of the movement of the intermediate water-masses in detail, as a much larger material is required for that purpose, especially from the north-western region and for the different periods of the year. From such investigations we should further learn, to what extent the intermediate layer is mixed in winter with the surface-layer and thus obtain more detailed information regarding the important question of the ventilation of the bottom-water.

Whilst the salinity of the intermediate layer varies but little in the Western Mediterranean, namely from ca. 38.7 ‰ at the Pantellaria Channel to ca. 38.4 ‰ at Gibraltar and only varies extremely little in the course of the year, there is above this a surface-layer with considerable variations in salinity. The surface-layer here as in the eastern basin is taken in a somewhat extended sense, meaning therewith the layer of water which undergoes great changes in the course of the year, and as we have seen, that an intermediate minimum of temperature occurs practically everywhere in the western basin of the Mediterranean, arising from the cooling from the surface in the preceding winter, it is evident, that this minimum gives a natural boundary for the surface-layer.

With regard to the vertical distribution of the salinity also, the temperature minimum usually gives a natural boundary between the surface water and the intermediate layer, as the salinity is as a rule low in the former and varies more or less greatly in a vertical direction, but below the depth at which the temperature has its minimum value, the salinity gradient becomes small, then nothing and changes sign in the intermediate layer, so that the temperature minimum lies on the boundary between two layers of water with respectively steep and fairly small, vertical, salinity gradients.

The principal factor in the horizontal variation of the salinity of the surface-layer is the Atlantic water flowing in through the Straits of Gibraltar; the salinity of the latter naturally undergoes changes in the course of the year, but these seem to be fairly small and both for the summer and winter the observations show a salinity at the surface outside Gibraltar of a little over 36 ‰, decreasing slowly as a

rule with the depth. In Sect. 20, Pl. IX, from Cape Trafalgar to Cape Spartel, taken in June 1910, the salinity in the Atlantic water is 36.1—36.2 ‰ down to 175—200 m., where a rather sudden rise sets in. Thus at St. 97 the salinity rises over 1 ‰ from 175 to 200 m., at St. 95 0.6 ‰ from 150 to 175 m. and also 0.6 ‰ from 175 to 200 m. At greater depths there is a fairly even increase in salinity, and it seems, therefore, that the boundary between the Atlantic water and the undercurrent from the Mediterranean approximately coincides here with the 37.0 isohaline, which lies at a depth of about 200 m. Below this lies a layer over 200 m. thick with a salinity of 37—38 ‰ and we thus see, that the Mediterranean water in its passage through the Straits of Gibraltar has become appreciably mixed with Atlantic water.

In September the salinity at the surface between Trafalgar—Spartel (Sect. 21) is somewhat higher than in June, namely, 36.3—36.4 ‰, but as the salinity now decreases with the depth and a layer over 100 m. thick with a salinity below 36 ‰ is found on the south side at St. 229, we may probably conclude that the whole body of inflowing water remains almost unchanged as regards salinity. As in June the boundary between the surface-current and the undercurrent is much more marked on the south side; here there is a rise in the salinity of 1 ‰ from 225 to 250 m., whilst almost the same increase on the north side occurs between 175 and 225 m., from which it appears, that the boundary for the Atlantic water also lies somewhat deeper on the south than on the north side, whilst, on the other hand, the thickness of the latter layer has increased by almost 50 m. since June.

From the winter cruise we have no observations in this section, as St. 63 lies somewhat further to the west and is not directly comparable with those mentioned above, because the thickness of the Atlantic water increases rapidly towards the west; at St. 63, further, there is a surface-layer over 100 m. thick with a uniform temperature (almost 15°) and salinity 36.27 ‰, which shows, that the salinity of the Atlantic water is a little higher in winter than in summer outside the Straits.

From the stations 98 and 99 at the Straits of Gibraltar we see, that the boundary between the two layers of water lies at Tarifa between 100 and 150 m. and in the Alboran Sea a little inside the Straits between 50 and 100 m., nearer 100 m. to judge from the temperature. Here no noteworthy change in the thickness of the Atlantic layer seems to have taken place until September (St. 228) and in both cases we find quite the same salinity — a little over 38 ‰ — at a depth of 150 m. On the other hand, the winter observations give a much less thickness for the Atlantic water in the neighbourhood of Gibraltar, as we at St. 60 already find over 37 ‰ at 50 m., but the stiff to hard easterly wind blowing at the time the observations were being taken, may perhaps to some extent have reduced the inflow of the Atlantic water and contributed to this result. As the evaporation from the surface of the Mediterranean is greatest in summer, it is only to be expected, that the inflowing quantity of water, which in a unit of time passes through the Straits of Gibraltar, would have its minimum in winter and thereafter increase in the course of the summer. It appears further from the temperature observations, that the inflowing surface water has in winter a higher, in summer a lower temperature than that which is found at the surface in the Western Mediterranean.

During its movement towards the east the surface-water becomes concentrated gradually by evaporation, but the increase in the surface salinity is still slight in the Cape de Gata section, where in June values as low as 36.5 ‰ are found. The boundary between the Atlantic surface-water and the Mediterranean is here no longer so sharp as in the Straits of Gibraltar, the increase of the salinity with the depth seldom amounting to 1 ‰ over a distance of 50 m. We see, therefore, that a mixed product is formed on the underside of the Atlantic water from this and the Mediterranean water. In this mixed layer lies the boundary between the east-going surface-current and the intermediate layer flowing in a westerly direction, but at what depth the direction of the movement changes cannot be determined and it is probable further, that the velocity in this transition-layer is small.

If we consider Sect. 18, for example, we find a temperature minimum in 200 m. at St. 108, in 150 m.

at St. 107 and about 300 m. at St. 106; the salinity in these depths is 38.2—38.3 ‰, and it is evident that this layer cannot move eastwards, as a temperature minimum cannot be formed at these depths in the Alboran Sea, where the surface-layer has a low salinity throughout the year. With regard to this section we may say, therefore, with certainty, that the thickness of the east-going surface-layer does not exceed 150 m. in June 1910, whilst on the other hand we may conclude, that water with a salinity much under 38 ‰ must move towards the east, and we come therefore to the approximate conclusion, that the boundary between the two opposite currents in the Cape de Gate section falls nearly at the 38.0 isohaline; for the transport of fresh water to the Mediterranean, further, it is of but little importance, whether the water about 38 ‰ takes part in the east-going movement or not, as the Atlantic component in this mixed product is fairly small.

In February 1909 there is a layer of about 100 m. in thickness in the southern part of the Cape de Gata section (Sect. 17), in which the salinity is below 37 ‰, but the salinity increases greatly towards the north and is about 1 ‰ higher at Cape de Gata; the 38.0 isohaline lies here at a little over 75 m., whereas it is almost at double that depth on the south side. As will be shown in more detail below, we may conclude from this distribution of the salinity, that the velocity of the current in the surface-layer must be at this time much greater in the southern than in the northern part. In June (Sect. 18) the thickness of the layer with salinity below 37 ‰ is only ca. 70 m. on the south side, but on the north side we now find just as thick a layer with the same salinity; in the central part of the section there is only ca. 10 m. nearest the surface with so low a salinity and the 38.0 isohaline also lies here somewhat higher than both to the north and south where it is found in a depth of about 125 m.

The thickness of the Atlantic surface-layer has greatly increased from June to September, the layer below 37 ‰ is about 75 m. towards the south and now increases towards the north, where it is over 150 m. The depth at which the 38.0 isohaline lies, also increases from ca. 125 m. at the southernmost station to ca. 225 m. at the northernmost. The cross-section area of the water-masses below 37 ‰ is thus ca. 4 times as great in September as in June, whilst the mixed layer 37—38 ‰ is almost unchanged; at the same time there has been a shifting downwards of the intermediate minimum of temperature, which is specially obvious in the middle of the section, where in June it was found at 150 m. (with the value 12.92°) and in September at 300 m. (12.95°), at which time a temperature of 14.09° occurred in 150 m. This extension downwards of the Atlantic water has thus led to a rise of temperature in 150 m. of over 1° — at 100 m. even of 2° — which shows with all desirable clearness, how little importance we can attach to the investigations on the transmission of heat downwards in the sea in the cases, where there is no guarantee that changes in the masses of water have not occurred in the interval; movements of the water can produce changes of temperature, which are many times greater than those due to the heating or cooling of the surface at the place itself.

Along the coast of Africa the salinity only increases slowly towards the east; thus off Algiers in June we find 36.62 ‰ at the surface and the 38.0 isohaline lies here almost at 150 m.; in the beginning of September the salinity is somewhat higher at the surface (36.74 ‰) but now decreases somewhat with the depth and has a minimum at about 36.5 ‰ in 25 m.; the 38.0 isohaline also lies now between 125 and 150 m. but yet a little higher than in June. Between Sardinia and Tunis but nearest the coast of the latter a surface-layer of 37 ‰ (down to 75 m. at St. 45) is found in the winter of 1909 and the 38.0 isohaline lies (Sect. 13) in 200 m., where the intermediate minimum of temperature is also found. Somewhat further to the east (Sect. 8A) in July 1910 the intermediate minimum of temperature lies nearer the surface with the 38.0 isohaline up between 125 and 150 m., and the salinity at the surface is now somewhat above 37 ‰, though we find a little under 37 ‰ about 50 m. at St. 134.

Whilst the salinity at the surface thus only increases about ½ ‰ from the Alboran Sea to near

the entrance to the eastern basin, there is a much greater increase towards the north in the Balearic Sea. In Sect. 14 from Algiers to Genoa we see, that the surface-salinity increases almost 1 ‰ from St. 113 to St. 116 and the layer with salinity below 38 ‰ also decreases in thickness from about 150 m. at Algiers and quite disappears a little north of St. 118, where a salinity of almost 38.3 ‰ even occurs at the surface and there is very little variation in a vertical direction. In the northernmost part of the section, at the Ligurian coast, we again find values under 38 ‰ in a narrow belt, which almost has the character of coastal water, and as similar values occur in the northernmost part of the Tyrrhenian Sea, we may probably conclude, that the coastal water at the Ligurian coast comes from the Tyrrhenian Sea, so that an outflow from the Tyrrhenian Sea into the Ligurian Sea occurs not only intermediately but also in the surface-layer and the surface-current also seems to bend towards the right side of the basin.

From Algiers towards the north-west (Sect. 16 A) there is also an increase in the salinity of the surface-layer and a diminution in the thickness of the fresher layer, yet below 37.5 ‰ is still found in the neighbourhood of the surface to the north-west of Iviza, but from here the salinity increases somewhat strongly towards the north-east and at St. 209 between Barcelona and Minorca we find a surface-layer with somewhat over 38 ‰, thus values which are only a little lower than those we found west of Corsica at the end of June.

Very interesting conditions are found in the surface-layer in Sect. 15 A from Barcelona to the south point of Sardinia; nearest the Spanish coast there is a border of coastal water with a little below 38 ‰ down to ca. 75 m., but from here towards the Balearic Isles the salinity in the surface-layer is everywhere above 38 ‰. East of the Balearic Isles the salinity at the surface at St. 206 is somewhat lower than at the corresponding St. 116 in June, but the value is 38 ‰ already at 70 m., which was met with in June first at 100 m. and about midway between the Balearic Isles and Sardinia very low values were found for the surface-salinity. The lowest value 37.09 ‰ was observed at 6° 44′ E. L., 39° 01′ N. L., and from here the salinity at the surface increases 1.1 ‰ to St. 204, a distance of only 1 degree of longitude. From St. 204 the salinity at the surface remains fairly constant about 38.2 ‰ along the south coast of Sardinia, whilst a little below the surface we meet with a fairly thin layer with a little under 38 ‰.

From this distribution of the surface-salinity between Sardinia and the Balearic Isles it appears, that a transport occurs through this section of masses of water, which have a surface salinity almost as low as in the east-going current at the coast of Tunis, and that the surface-salinity east of the Balearic Isles is reduced somewhat in the course of the summer in consequence of this north-going movement. As the salinity at the surface is over 38 ‰ at a considerable distance west of Sardinia, we see, further, that the surface-water from the Tyrrhenian Sea spreads out through the Sardinia Channel on its northern side, then gradually bends in a northerly direction presumably along the west coast of Sardinia, separating this from the fresher surface-water, until it gradually becomes mixed with the latter. Just as in the northern outlet from the Tyrrhenian Sea, therefore, the surface-water in the Sardinia Channel also seems to have the same direction of movement as the intermediate layer.

From the above distribution of salinity in the surface-layer in the Western Mediterranean we may readily understand the main features of its movement. As the inflow of Atlantic water through the Straits of Gibraltar compensates for the loss of the Mediterranean from evaporation, it is evident, that the intensity of the inflow must have a yearly period with a minimum in the winter — probably towards the end of this — and maximum in summer, probably also towards the end, as the volume of river water is then least (an exception to this, however, is the Nile, which has a maximum volume in August—September [Craig 1910, p. 45, Lyons 1906, p. 279]).

It appears from the observations in the Cape de Gata section, that the volume of the Atlantic water in the Alboran Sea is least in February 1909 and greatest in September 1910; at the former period

the Atlantic water mainly occurs on the south side at the coast of Africa, whereas in summer it has spread in almost unmixed form over the whole of the Alboran Sea. Further to the east the whole of the surface-layer between the Balearic Isles and the coast of Algiers — at least in the summer — is influenced by the east-going Atlantic water, but the volume of this layer is greatest (about 150 m.) at the coast of Algiers, from which the thickness decreases like a wedge towards the north, at the same time as its salinity increases by mixing with the Mediterranean water. Whilst the major portion of the Atlantic water continues its movement eastwards towards the Sardinia Channel, a portion flows to the north-east and north between the Balearic Isles and Sardinia, and the kernel of the north-going current in September lies about 7° E. L., thus nearer Sardinia, but is separated from this island on the southern part of its west coast by a belt of surface-water, which has flowed out from the Tyrrhenian Sea.

Thus, the Sardinia Channel is not filled by the east-going surface-layer in the whole of its breadth, as there is a movement of the surface-water from the Tyrrhenian Sea in an opposite direction on the south coast of Sardinia. Nor does the whole quantity of Atlantic water, which passes through the Sardinia Channel, reach the Eastern Mediterranean; as we have seen earlier, a parting occurs between Sardinia and Sicily and a not unimportant portion goes into the Tyrrhenian Sea along the north coast of Sicily and towards Italy bends towards the north and north-west along the south-west coast of Italy.

A portion of these water-masses undoubtedly continues as a current along the coast and spreads over the greater part of the water between Italy and the north point of Corsica, thereafter flowing out into the Ligurian Sea, but there are features which indicate, that a division of the surface-current must take place almost at the latitude of Naples, and a part of its water-masses bends in a westerly direction. At St. 128, namely, we find a fairly high salinity in the surface-layer, and at St. 127 the salinity at the surface is still higher, namely almost 38.4 ‰, whilst at St. 129 we find a surface-layer with a little below 38.0 ‰, and here also the intermediate minimum of temperature coming from the winter cooling is least marked, which indicates that a more rapid renewal of the surface-layer occurs in winter than at the more northerly stations. This, in conjunction with the fact, that surface-water from the Tyrrhenian Sea occurs south-west of Sardinia, makes it probable, that the surface-layer flowing north-west along the Italian coast divides possibly off Naples, one portion bending towards the west and later south-west towards the Sardinia Channel, where it again leaves the Tyrrhenian Sea after making a movement of rotation in this.

How the movement of the Atlantic surface-layer, which goes northwards between Sardinia and the Balearic Isles, is continued, does not appear directly from our observations. It is evident, however, that the great differences in density between the Atlantic water and the saline and heavy surface-layer, which we found in June west of Corsica, will tend to be smoothed out in the course of the summer. As we shall see below under the vertical circulation, the whole of the north-western part of the Balearic Sea is covered in winter by a salt and cooled, consequently heavy, surface-layer, from which a descent may take place even to the greatest depths, and even though the masses of water found in the surface-layer in June do not have a sufficiently high density to sink down to the bottom-water, yet there will be a tendency towards a descending movement of the surface-water, followed by an inflow of the much lighter surface-water from the south-east. As we have seen, further, that there is a surface-layer in Sect. 15 A at the Spanish coast with relatively low salinity, which has probably come from the north, like the salter, intermediate layer occurring here, it is extremely probable, that the surface-layer, which flows northwards to the west of Sardinia, gradually bends towards the west and later towards the south along the coast of Spain, and that the movement of the surface-water itself proceeds in this way, is also apparent from the drift of bottles in the Balearic Sea; one of these thrown out in the autumn of 1898 even shows a current of over 8.5 miles per day for the distance from North-Western Sardinia to the western part of the Gulf of Lyons[1].

[1] See Annalen der Hydrographie etc. 27, p. 288. 1899.

In the main features, therefore, the movements of the surface-layer and of the intermediate layer are in the same direction; in the Tyrrhenian Sea there is an inflow west of Sicily and a cyclonic rotation (during which a minor portion flows out towards the north) with an outflow through the Sardinia Channel (for the surface-layer, only in the northernmost part of this); in the Balearic Sea likewise in the main a cyclonic rotation, with an outflow from the intermediate layer towards the west through the Alboran Sea and the Straits of Gibraltar.

It is probable, that an east-going movement in the intermediate layer also occurs along the coast of Algiers; this layer is in fact separated here from the Atlantic surface-layer by a layer with a minimum of temperature, and as a somewhat warmer surface-layer with low salinity occurs throughout the whole year, it is not possible, that this minimum can have arisen here from the cooling of the surface; it must have been produced by an inflow of cooled water-masses at this depth, and we are led naturally to think of the more northern parts of the Balearic Sea as the place where this cooling process has occurred. As the temperature minimum lies on the boundary between the intermediate layer and the surface-layer and, as is shown by the presence of the minimum in the Alboran Sea, rather follows the movement of the intermediate layer, which tends northwards to the west of Sardinia, it is very probable, that the intermediate layer off the coast of Algiers only appears here after a circulation in the Balearic Sea. The intermediate layer would thus form a closed circuit in the Balearic Sea, although the amount which goes eastwards along Algiers is perhaps small in comparison with what leaves the circuit and moves westwards through the Alboran Sea to the Atlantic.

With regard to the bottom-water, the horizontal distribution of temperature and salinity is marked by great uniformity within the same region, just as in the eastern basin. If we use the same index for the boundary between the intermediate and bottom layers, namely, the beginning of the uniform salinity and minimum for the temperature, then the boundary for the bottom-water in the Balearic Sea lies as a rule at a depth of 800—1000 m., whereas it was first met with about 2000 m. in the Tyrrhenian Sea.

In the Balearic Sea with its border regions we find, just as everywhere in the Mediterranean, an increase in the temperature of the bottom-layer with increasing depth, but in a horizontal direction the variations are but slight and, as the accompanying table shows, do not amount to 0.1° at depths of 1500 and 2000 m. In 1500 m. the temperature seems to be a little lower at the stations round the Balearic Isles than at the others. At a depth of 1000 m. the horizontal variation is still fairly small; towards the Sardinia Channel as at St. 35 near Monaco the values are over 13° — in both cases as the result of a slight influence from the intermediate layer — but even when these stations are excluded, there is a difference of about 0.2° between the different values in 1000 m. The lowest temperatures are found about the Balearic Isles, the absolutely lowest 12.76° at St. 215 north-west of Iviza, 12.80° north of Majorca, but between the Balearic Isles and Algiers also the values are distinctly somewhat lower than the others.

The salinity at depths over 1000 m., on the other hand, does not show any regularity; all the values observed during the summer cruise, which must be considered to have been somewhat more accurately determined than those of the winter cruise, as mentioned in discussing the determinations of salinity, lie between 38.35 and 38.39 ‰. This interval is so small, that all the variations can be referred to errors of observation, as the absolute values can scarcely be considered to have been determined with greater exactness than 0.02 ‰, an uncertainty that just gives the extreme values (38.37 ‰ $\pm$ 0.02). On the other hand, there is no doubt, that the salinity of the bottom-layer in the Tyrrhenian Sea is a little higher than in the Balearic Sea, though the difference is only about 0.05 ‰.

We thus have very few points of support for the solution of the question, what horizontal movements occur in the deep water of the Western Mediterranean, or if such occur on the whole. As we shall see below in discussing the vertical circulation, strong vertical currents must occur in winter in the northern

Date	Station	Temperature				Salinity			
		1000	1500	2000	2500	1000	1500	2000	2500
Alboran Sea									
1909 II 20	59	12.96	—	—	—	38.39	—	—	—
" " 19	54	93	—	—	—	37	—	—	—
1910 VI 24	106	89	—	—	—	37	—	—	—
" IX 5	224	88 [1]	—	—	—	38 [1]	—	—	—
1909 II 18	53	94	12.94	—	—	39	38.39	—	—
1910 VI 25	107	88	93	12.99	—	37	36	38.37	—
" IX 5	223	92 [1]	93	97	—	39 [1]	39	39	—
1909 II 18	52	91	93	99	—	39	40	42	—
1910 VI 25	108	88	93	—	—	37	35	—	—
Between Spain and the Balearic Isles									
1910 VIII 31	215	76	—	—	—	35	—	—	—
" " 29	209	80	87	—	—	37	39	—	—
Ligurian Sea									
1909 I 28	35	13.04	96	13.05	—	44	42	42	—
1910 VII 2	122	12.91	—	—	—	39	—	—	—
" " 9	125	91 [2]	—	—	—	37 [2]	—	—	—
Balearic Sea									
1910 VII 1	120	88	96	01	13.06	37	37	38	38.37
1909 I 30	37	91	94	01	—	39	35	35	—
1910 VI 30	118	90	94	01	07	37	37	39	39
" " 29	116	86	92	—	02 [3]	37	35	—	38 [3]
" VIII 28	206	83	94	12.98	02	37	38	37	37
" " 27	204	92	—	—	—	39	—	—	—
" VI 28	115	84	88	13.00	04	36	37	39	37
" IX 1	217	84 [1]	91	—	—	36 [1]	38	—	—
1909 II 16	50	91	93	12.99	—	40	40	46	—
1910 VI 26	112	86	93	99	—	35	36	35	—
1909 II 8	47	91	94	13.00	—	37	37	39	—
" " 7	46	94	95	00 [4]	—	33	33	33 [4]	—
" " 6	45	13.02	96	12.99	—	40	35	35	—
" " 3	43	18	13.02	13.01 [5]	—	44	37	37 [5]	—
Tyrrhenian Sea									
1909 II 2	42	19	—	—	—	49	—	—	—
1910 VII 14	132	24	16	—	—	48	44	—	—
" VIII 25	199	25	—	—	—	49	—	—	—
" VII 12	129	42	21	18	20	53	46	42	40
" " 11	128	32	19	—	—	51	46	—	—
1909 I 21	31	25	—	—	—	44	—	—	—
" " "	30	40	22	—	—	51	49	—	—
" " 16	24	49	25	—	—	51	46	44	—
1910 VIII 24	197	38	—	—	—	55	—	—	—
" " 21	195	33	17	13	—	49	46	42	—

[1] 950 m. [2] 1050 m. [3] 2400 m. [4] 1900 m. [5] 1950 m.

part of the Balearic Sea, with a descent of new masses of water to the bottom-layer, whilst the fresher surface-layer over the whole of the southern part renders a vertical circulation to great depths impossible. From a similar process of reasoning to that we have used earlier for the eastern basin (p. 138), we may conclude, that horizontal movements occur in the Balearic Sea, whereby bottom-water is

carried from its northern to its southern part, and the distribution of temperature discussed above might indicate, that the bottom-water is by this movement carried past the Balearic Isles down towards the coast of Algiers, and it is probable, therefore, that a closed circuit is also present in the deep water, with a north-going movement towards the west coast of Sardinia. It is also reasonable to conclude, that the circulation in the intermediate layer is transferred by friction to the bottom-layer, so that the latter also follows a similar circuit, though probably with a less velocity.

In the Tyrrhenian Sea the bottom-water at depths greater than 2000 m. is shut off from connection with the Balearic Sea; for these great depths our material is not sufficient to elucidate the horizontal changes that may take place. The bottom-water seems almost to come from the Balearic Sea; the constant salinity and temperature increasing towards the bottom seem to me to show this; but we see, nevertheless, that this bottom-water during the inflow through the Sardinia Channel has become somewhat mixed with the intermediate masses of water in the Tyrrhenian Sea.

The horizontal circulation in the Western Mediterranean thus seems to consist in the main of two cyclonic rotations independent of one another, in which all three layers of the Balearic Sea and both the surface and intermediate layers of the Tyrrhenian Sea seem to take part as one whole. The movement receives its special character from the surface inflow of the Atlantic water from the west and the intermediate inflow from the eastern basin. The cause of the rotatory movement must be sought for mainly in the deflecting influence of the earth's rotation, though the cooling and the consequent descent of surface-water in the northern part of the Balearic Sea is scarcely without importance for this Sea, especially for the movement of the surface-layer. The actual cause of the horizontal circulation is the evaporation from the Mediterranean, especially from its eastern part, and is thus due in the last instance to the fact, that the rainfall and river-water is not sufficient to compensate for the loss of water by evaporation.

3. The vertical circulation in the Western Mediterranean.

In the foregoing we have repeatedly touched upon the vertical circulation in the Western Mediterranean and this question, which is so important for the fauna and flora of the deeper layers, may now be studied more closely. As a condition for the propagation of a vertical movement from the surface downwards it is necessary, that the density of the surface-water should be greater than that of the deeper layers, but we have already seen, that this condition is not sufficient; it is also necessary, that the density should decrease downwards with values, which are as great as those given on p. 145 and represented in fig. 13, p. 145, as the whole column of water is in indifferent equilibrium when the density has precisely the gradient indicated.

We have already shown, that the vertical circulation from the surface cannot reach to very great depths in the whole of the southern part of the western basin, owing to the fact, that the surface-layer here has a relatively low salinity and further is not subject to intensive cooling. Of a mixing of the surface-layer with the intermediate layer in consequence of the cooling of the former, there can thus be no question, as the surface is as a rule hardly cooled to a lower temperature than that of the intermediate layer and at the same time has a much lower salinity than the latter. Thus, the surface-layer here as in a great part of the Eastern Mediterranean, acts as a protection to the intermediate layer against cooling from the atmosphere.

The Western Mediterranean, however, extends a comparatively great distance towards the north and over its northern parts, the Ligurian Sea and the northern part of the Balearic Sea, the conditions are very different. In winter fairly strong and cold north-west winds are prevalent [Seewarte 1905]

and further, the surface-layer is much less influenced by the Atlantic water than in the southern part, so that the difference in density between the surface and the deeper layers is much less. At St. 120 west of Corsica, for example, the density at 100 m. is just as great as at 2500 m., but the highest value for the density occurs in the intermediate layer about 200 m., where however it is only 0.00006 higher than at 100 m. Although the salinity at the surface is about 38.3 ‰, this is no evidence that a descent of surface-water to the deeper layers has taken place here; nor do we have serial observations of temperature and salinity showing a column of water, which is in indifferent equilibrium in the whole of its extent, but on the basis of a few of our stations in conjunction with the surface observations made from various ships in the winter of 1910, we can form some notion as to how and within what region this exchange takes place.

The salinity at the surface in the northern part of the Balearic Sea and in part in the Ligurian Sea, which is fairly high in the beginning of the summer, decreases towards the autumn as the result of an inflow of surface-water from the south. Even though we do not know the exact distribution of the surface-salinity, we may probably assume, that it is very near to 38 ‰, a value we find for the Ligurian Sea at any rate from Capt. STRUBBERG's observations from the SS. Arno in September 1909. As the air temperature gradually decreases, the surface becomes cooled and nearest this a layer is formed with constant temperature and constant salinity, the thickness of which increases as the cooling advances. This surface-layer with uniform temperature and salinity is found at numerous stations on the winter cruise of 1908—1909, but it reaches its greatest extension at St. 37, in the northern part of the Balearic Sea at a considerable distance from land, at the end of January 1909.

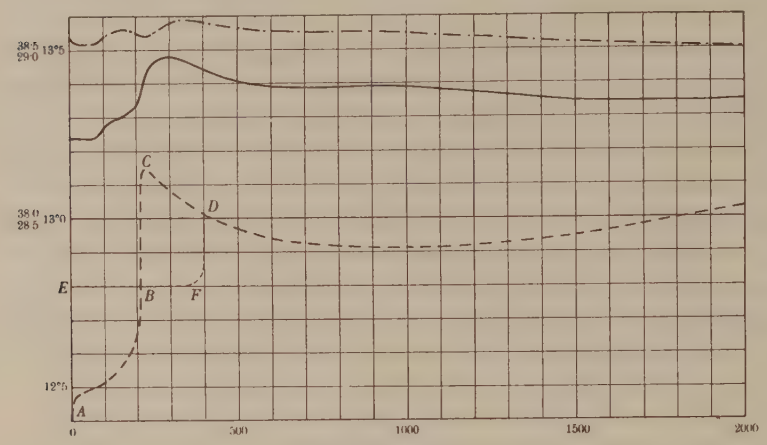

Fig. 19 (St. 37).

From fig. 19 we see, that the temperature at St. 37 has its lowest value 12.4° at the surface and only increases slowly with the depth down to 200 m.; the salinity at the surface is 38.24 ‰ and likewise increases slowly with the depth, so that the density in the surface-layer is almost quite constant (variations of 0.02 in σ_t may arise from uncertainty in the titrations). Between 200 and 225 m. there is a sudden jump in the temperature of about $^1/_2$ °, and it is evident, therefore, that already at the end of January the cooling from the surface-layer has reached down to a depth of about 200 m., and as the cooling of the surface is continued throughout the whole of February and greater part of March (NATHANSOHN 1909, p. 25), it is obvious, that it spreads still deeper before the end of the winter. From the density at the surface we see, that when the surface-water is further cooled down 0.1°, it obtains the same density as that existing at 200 m. and a further cooling will thus cause the surface-water to sink down deeper and be replaced by water from the deeper layers. A cooling of 0.2° produces in the surface-water just as high a density as the maximum in 300 m., and a further slight cooling produces an unstable condition, which results in a descent of the surface-water to depths greater than 300 m.

As a descent of the surface-water is accompanied however by an ascent from the deeper layers, producing in short a vertical circulation by which the whole layer of water is mixed down to the depth reached by the surface-water, we see, that a cooling of the surface will increase the salinity of the sur-

face-water through an increase of the depth of the vertical circulation. If we imagine the vertical circulation extended to 400 m., for example, a mixing of the layer from 0 to 400 m. will produce a salinity in this of over 38.35 ‰ or about the same value as we find at 2000 m., and the condition for equilibrium is then, according to what we have seen p. 143, that the difference between the temperature at 2000 m. and at the surface does not exeed 0.31°, so that the surface-water will sink down to a depth of 2000 m. when its temperature sinks below 12.7° after a mixing such as that assumed.

It is not only the salinity of the surface-layer, however, which is changed owing to a mixing process reaching down to a depth of 400 m.; as there is a higher temperature from 225 to 400 m. it is evident, that the product of mixing must assume a temperature which is higher than that of the surface-layer and we see from the figure, that this temperature may become ca. 12.8° (represented by the faintly dotted curve EBFD, which is determined by the area ABE being equal to BCDF). Thus, whilst a cooling of the surface-layer by ca. 0.2° down to 200 m. may lead to a mixing such as that described, a rise in the temperature of the surface-layer will be produced by this cooling, however remarkable it may sound. If we assume, namely, that a cooling of 0.2° spreads first of all to 200 m., and that the mixing with the following layer almost 200 m. thick then takes place, we see, that the product of mixing has assumed a temperature of ca. 12.7° down to 400 m., in spite of the cooling which has produced the mixing.

The density curve in fig. 19 along with the curve for the density distribution under the condition of indifferent equilibrium in fig. 13 shows, that the whole column of water here as everywhere in the Mediterranean is very nearly in indifferent equilibrium from the salinity maximum in the intermediate layer down to the bottom. If we take the mean value of the density from the surface down to 300 m., where the maximum occurs, as 29.04, we see that when the density is increased by 0.03—0.04 the equilibrium becomes indifferent through the whole column of water. If we imagine such an increase in the density arising from cooling of the layer down to 300 m., this will occur when the temperature is reduced by ca. 0.2°, which means a loss of heat of approximately ca. 6000 gm.-cal. per unit of surface, a loss which is small by comparison with the yearly exchange of heat through the surface.

When a further loss of heat occurs from the surface, this will lead to a descent of surface-water to depths of 2000 m., and it appears from the factors determining this vertical circulation, that when a product arises from the mixing of the surface-layer with the intermediate masses of water, which has a higher salinity than the bottom-water, then salter water with a higher temperature will be brought down to the latter by the vertical circulation, whilst a product with lower salinity will bring to the bottom-layer less saline masses of water with a temperature, which is lower than that present beforehand.

A continuation of the vertical movements for a longer period will naturally not change the uniform salinity produced by these, whilst the temperature will gradually become reduced through the whole layer of water, in consequence of the continued loss of heat from the surface. Even if great fluctuations from year to year can scarcely occur in the temperature and salinity owing to the great volume of the bottom-layer (especially as such changes only arise in comparatively restricted regions and will be partly effaced by the horizontal circulation in deep water), yet such fluctuations may nevertheless occur. No difference however can be shown with certainty in the conditions in deep water in 1908—1909 and 1910.

It appears from the conditions at St. 37, as shown above, that a fairly slight cooling will produce a mixing of the surface and intermediate layers and thereafter a descent of this mixed product to the bottom-water. As this station was investigated at the end of January, there was reason to believe, that such a cooling really takes place and to determine this several series of surface-samples were collected along with the temperature observations in February and March 1910. Through the friendly assistance of Dr. Nissen, the Danish Consul-General in Algiers, these investigations were successfully carried out from the French and German steamers running between Algiers—Marseilles and Algiers—Genoa. From these it appears

that the cooling of the surface-water is continued during February, and that the lowest values for the surface temperature are first met with in March, which agrees also with the observations made from Monaco [NATHANSOHN 1909, p. 24—28]. At the same time the surface-salinity increased, and values of 38.40 ‰ or even a little higher were observed in the first half of March both on the route to Marseilles and to Genoa.

In the first half of March 1910 Capt. STRUBBERG of the SS. "Arno", Copenhagen, undertook an important series of observations from Cape de Gata to Leghorn, which showed that a fairly high salinity occurred everywhere over the whole stretch from a point north-west of Majorca to north of Corsica, the values with only few exceptions lying over 38.3 ‰. North of the Balearic Isles 3 successive observations gave 38.40—38.42 ‰, and west of Corsica 7 successive observations between ca. 5° and 7° E. L. gave the values 38.42—38.46 ‰, whilst the temperature over the whole stretch from the Balearic Isles to Corsica varied from 12.5° to 13°.

It appears from these observations, on the one hand, that a mixing of the intermediate and surface layers has taken place, as such a high salinity at the surface cannot occur here in any other way; on the other, that the difference in density between the surface and bottom-water is greater than the calculated value corresponding to the condition of indifferent equilibrium, with the result that a descent of surface-water to the greatest depths must necessarily occur at these places. During this process, as has been shown under the vertical circulation in the Eastern Mediterranean, a layer of water will be formed with uniform salinity from the surface to the bottom and a temperature distribution with minimum at the very surface, but increasing downwards with values, which can be calculated from Lord KELVIN's formula for the change of heat during adiabatic change of volume.

Although the final result of such a vertical circulation, produced by cooling from the surface, may be taken for granted, it would be of great importance to have a vertical series of temperature observations and analyses just during such a process. It would especially be of interest to determine the divergence of the vertical density gradient from the value corresponding to the condition of indifferent equilibrium, and the velocity with which the movement proceeds downwards, which would give a means to estimate the inner friction, a factor which is of great importance for the circulation in the sea, but about which extremely divergent views prevail. The Oceanographical Institute at Monaco, which in recent years has made the vertical circulation in the Mediterranean the object of close study, will undoubtedly solve this question, for which purpose its favourable situation in the neighbourhood of great depths, where these processes are going on, affords it peculiar advantages.

Shortly after our investigations described above were made, namely on April 7 th 1909, the following observations were made from Monaco at 43° 22′ N. L., 7° 35′ E. L. [NATHANSOHN 1910, p. 12]:

	t	Cl.	σ_t (calculated)
0 m.	12.67°	21.32	29.20
2213 —	12.97°	21.31	29.13

These observations show, that even so late as this period the column of water is in indifferent equilibrium, as the difference in density 0.00007 has just the same dimension as that calculated above, and if any cooling of the surface occurred still later, this would cause a descent of the surface-water to the bottom. Thus, the vertical circulation here still has favourable conditions in the beginning of April for reaching down to the greatest depths, if a period occurs during which the surface-water becomes further cooled.

Whilst the ventilation of the bottom-water in the Eastern Mediterranean, as we have already shown, has its source in the water cooled down in the northern border-regions — the Aegean Sea and Adriatic — this process assumes much greater dimensions in the Western Mediterranean. The surface observations

discussed above show, that the whole of the northern part from the Balearic Isles to the south-western part of the Ligurian Sea is subjected to a strong cooling process in the course of the winter, so strong indeed that the surface-water after mixing with the intermediate layer may sink down to the greatest depths. When this condition has once set in, the vertical circulation will be continued by further loss of heat from the surface, but we can readily see, that the temperature of this will only fall extremely slowly; assuming, for example, that the salinity is uniform and the temperature at the surface 12.70°, at 2000 m. 13.01°, the column of water is in indifferent equilibrium, and a cooling to e. g. 12.5° cannot take place without the surface-water sinking down and the temperature and density differences becoming levelled out by the vertical movement. This will only cease, when the whole column of water has been cooled down 0.2°, but such a small reduction of temperature represents in reality a loss of heat of $0.2 \times 100 \times 2000 = 40{,}000$ cal. per square cm. of surface.

In the neighbourhood of the coasts, on the other hand, where there is a belt of fresher water of more or less breadth, temperatures far under 12.7° may occur in winter, and especially in shallow water, where the whole body of water is rapidly cooled. For example, Aimé (see p. 84) found 11.3° as the mean temperature for the month of March at Toulon, but when such low values occur over great depths, they just show, that the water in these is prevented by a fresher surface-layer from taking part in a vertical circulation starting from the surface, since, whenever this begins, the surface-layer by mixing with the deeper layers will assume a temperature, which as a rule is scarcely below 12.5°.

So long as the water from the surface in the northern part of the Balearic Sea sinks down and spreads out in the deeper layers, there must be as compensation an inflow of the upper layers from the more southerly regions. After the cooling of the surface has ceased in the spring, there must be considerable differences in the surface-layer from north to south, which as already mentioned under the horizontal circulation will lead to an inflow of less saline surface-water to the north between the Balearic Isles and Sardinia, and from some samples taken by steamers in June and September along with our own observations, it also appears, that the surface-salinity in the north-western part of the Balearic Sea decreases in the course of the summer. A similar inflow also takes place undoubtedly in the intermediate layer in the course of the summer (in January 1909, for example, it is found at St. 37, but at the same station it may be assumed to have disappeared by mixing in the winter of 1908), whilst the relatively cold masses of water from the northern part probably move in a south-westerly and southerly direction (the intermediate layer is not found in September at St. 209 and it has almost disappeared at St. 206, whereas it was present in June at St. 116).

At places where the surface-salinity is lower or the cooling less intensive than in the northern part of the Balearic Sea, the surface-layer is cooled down to a depth dependent on these factors, without any mixing with the intermediate layer taking place. When this cooled layer is again warmed up in the summer, a minimum of temperature occurs, which separates the intermediate, salter and warmer layer from the heated surface-layer. This temperature minimum, which lies in general between 150 and 200 m., extends through horizontal movements over the whole of the basin and even occurs at the coast of Africa, where such low values for the surface-temperature are never found. The layer of water, in which the lowest temperature occurs and which rests upon warmer water, will naturally be warmed up somewhat, both from above and from below, until it becomes renewed during the cooling of the next winter.

In the Tyrrhenian Sea east of the Straits of Bonifaccio we find a fairly high salinity at the surface in the month of July, the highest value is 38.37, and it was not excluded therefore, that a vertical circulation might arise here in the winter from cooling, which could penetrate to great depths. It is not excluded, however, that the high values are only due to an inflow of surface-water from the Balearic Sea (this has undoubtedly occurred at the end of January 1909, leading to a high salinity at St. 38), but in

all cases any vertical circulation that may arise in the northern part will not attain a great extension to the south, and as the depths are relatively small in the northern part, a current of cooled water may in the most fortunate case flow along the bottom down the northern slope towards the greatest depths in the basin.

We have seen, however, that the intermediate layer in the Tyrrhenian Sea has a much greater volume than in any other part of the Mediterranean, and that both the temperature and salinity, from the maximum values in the intermediate layer down to depths of about 2000 m., seem almost to have been derived from slow processes of mixing and are essentially different from the distribution, which arises from the surface from a disturbance of the equilibrium. This indicates, that the descent of water from the surface to the bottom-layer does not attain to any importance in the Tyrrhenian Sea. It is only at depths greater than 2000 m., that a distribution occurs agreeing with what we find in the other parts of the Mediterranean, uniform salinity and rising temperature towards the bottom, but this bottom-layer probably comes from the Balearic Sea, becoming a little mixed and thus assuming a somewhat higher temperature during its passage along the bottom through the Sardinia Channel. On flowing down thereafter towards the greatest depths in the Tyrrhenian Sea, its temperature rises by an amount corresponding to the increase in pressure.

In the southern part of the Balearic Sea, where the vertical circulation as in the Tyrrhenian Sea is restricted to the surface-layer alone, the temperature distribution at depths greater than 1000 m. is not essentially different from in the remaining part of the Balearic Sea. The temperature rises from depths of about 1000 m. down towards the bottom and between the above depth and the maximum for the temperature and salinity in the intermediate layer there is only a mixed layer some few hundred meters thick as transition to the bottom-water. Although the outer conditions for the extension of the intermediate layer in deep water are the same in the southern part of the Balearic Sea as in the Tyrrhenian, it seems to me, that the complete agreement between the conditions in deep water in the northern and southern part of the Balearic basin is the best evidence, that horizontal movements take place down to the greatest depths in the Mediterranean.

VIII. Exchange of water in the Mediterranean and the currents through the Straits of Gibraltar.

The fact alone, that the salinity in the Mediterranean is greater than in the Atlantic in spite of the connection between the two, shows that the quantity of water, which evaporates from the surface of the Mediterranean, is greater than the quantity of fresh water added to this basin by direct rainfall and by rivers. There is thus the probability, that the salinity of the Mediterranean has increased in the course of ages, but it is just as probable, that the total quantity of salt, though perhaps still on the increase, can be considered as approximately constant for a short period in geological regards, for example, a century, and it is undoubtedly quite permissible to consider the condition as stationary for such a short period as is dealt with here, and the following discussion is therefore based on this presupposition.

If we take the mean value for the evaporation in the course of one year, measured in cm., as e, whilst f is the height in cm. of the annual addition of fresh water, distributed evenly over the whole surface of the Mediterranean, then $e-f>0$, and the level of the Mediterranean would therefore fall by $e-f$ cm. in 1 year, if there were no inflow from the Atlantic. Even if $e-f$ became equal to 0 for a single year, the inflow through the Straits of Gibraltar would not cease, as the difference in density between the Atlantic

and Mediterranean means a difference of level, which will maintain a current system until the difference is equalized.

On the basis of Bourdaloue's measurements of level, this difference is given by Bouquet de la Grye [1882, p. 469] as 108 cm. between Marseilles and Brest, whilst from the difference in density between the Atlantic and the Mediterranean at Marseilles he calculates the value 102 cm. More recent measurement of the levels (cf. Lallemand [1890]) has, on the other hand, found no noteworthy difference in level and thus, if the newer results are more reliable than the older, comes into conflict with the elementary laws of hydrostatics. If we take the mean density in a column of water in Cadiz Bay as ρ and that of the Mediterranean water as ρ_m, whilst the height of two columns of water which exercise the same pressure are respectively h and h_m, we have $h\rho g = h_m\rho_m g$. For $h = 40000$ cm., which is almost equal to the depth in the Straits of Gibraltar, an approximate calculation will give the following, as $h - h_m = 40000\frac{\rho_m - \rho}{\rho}$:

Difference of level between	Cadiz Bay	and	St.	37	81	cm.		
—	—	—	—	—	—	- 120	81	—
—	—	—	—	—	—	- 118	72	—
—	—	—	—	—	—	- 116	69	—
—	—	—	—	—	—	- 206	63	—
—	—	—	—	—	—	- 160	76	—

If no other factors influence the difference of level, the surface in the northern part of the Balearic Sea will thus lie ca. 80 cm. and the surface towards Crete about the same amount lower than in the Bay of Cadiz, and even if these values differ perhaps a little from the actual, there can yet be no doubt, that the level of the Mediterranean is lower than that of the Atlantic, and that an inflow will take place for this reason. As we must assume, that a definite intensity of inflow will correspond to a certain difference of level, this inflow will proceed at an almost even rate, if no other factors are at work.

Of these, however, there are several. In the first place, the inflow in the Straits of Gibraltar is dependent on the prevailing winds; with westerly winds the water is heaped up into Cadiz Bay and the rate of flow increased, whilst it becomes reduced with easterly winds, which may even lead to a surface-current flowing out of the Mediterranean. But this is probably of rare occurrence. In the second place, the inflow is subject to changes of a periodic nature, a shorter with a daily period and a longer with a yearly period. The shorter, daily variation is due to the tidal movement in the Atlantic, the rate of flow increasing during highwater in Cadiz Bay and slackening at lowwater, whilst in the Mediterranean, owing to the smaller difference between low and highwater, the tidal current has much less influence.

The annual periodicity comes from the variation of $e-f$, and we have seen, in discussing the observations from the Alboran Sea and Straits of Gibraltar, that the inflow is least in winter and thereafter increases during the summer; this arises from the fact, that the value of e increases greatly with rising air temperature and reaches its maximum in the summer, whilst f decreases, partly because the greater portion of the Mediterranean belongs in summer to the rainless zone and partly because the quantity of water decreases in summer in most of the rivers running into the Mediterranean (an exception here is the Nile, from which the maximum flow is in August-September [Lyons 1906, p. 279]). As the maximum inflow probably sets in somewhat later than the maximum for $e-f$, it is reasonable to conclude, that the inflow reaches its greatest intensity in September or almost at the same period as the beginning of the rainy season, and its lowest value somewhat after the minimum for $e-f$, probably in February or March.

As mentioned in the foregoing, in discussing the inflow through the Pantellaria Channel, the necessary presuppositions for a stationary condition from one year to another are not only, that the total

quantity of water remains unchanged but also, that the total amount of salt remains unaltered. The quantity of salt which is brought in from the Atlantic in the course of the year must consequently be returned again to the latter, and this transport is conveyed by the undercurrent through the Straits of Gibraltar. This undercurrent, whose existence was incontestably proved by the discovery of CARPENTER, that bottom-water whith high salinity occurred in Cadiz Bay, carries considerable masses of water from the Mediterranean into the Atlantic. When it became so well-known, that Atlantic water is constantly flowing into the Mediterranean, we cannot but wonder, that the idea of this undercurrent met with so much opposition until within quite recent years.

If the annual amount of inflowing water is I kg. and its salinity S_i, whilst the outflowing is U and its salinity S_u, we have $I \cdot S_i = U \cdot S_u$ as the equation of continuity, meaning that the total quantity of salt does not change in the course of the year; from this we have:

$$U = I \frac{S_i}{S_u} \quad \text{and} \quad I - U = I \frac{S_u - S_i}{S_u}.$$

If we insert now the mean value for the salinity of the masses of water, which pass through the narrowest part of the Straits of Gibraltar, $S_i = 36.1\,‰$ and $S_u = 38.0\,‰$, we obtain:

$$U = I \frac{36.1}{38.0} = 0.95 \cdot I \quad \text{and} \quad I - U = 0.05 \cdot I.$$

We see from this, that only $^1/_{20}$th of the inflowing amount of water is evaporated in the Mediterranean, whilst $^{19}/_{20}$ths are transported back again to the Atlantic in concentrated condition.[1]

To obtain some conception of the dimensions of the inflow, we may consider the equation (4) p. 137:

$$I + F = U + E$$

which means, that the quantity of water received by the Mediterranean from the Atlantic and from rainfall and rivers, is equal to that which it loses by evaporation and outflow. We have $I - U = 0.05 \cdot I$ and thus obtain:

$$0.05 \cdot I = E - F.$$

For the Mediterranean, however, both E and F are only known very imperfectly. The amount of fresh water comes partly from the rain falling directly into the Mediterranean, partly from that falling over the adjacent countries, a portion of which finds its way with the rivers into the Mediterranean.

THEOBALD FISCHER [1879] estimated the annual rainfall over the Mediterranean countries to be 760 mm., but close examination shows, that this value is of little practical importance, as it is obtained from the arithmetic mean of the rainfall at all the stations, without regard for the area represented by the stations. Thus, there are many stations in the rainy region of the Po, whilst the extensive dry regions of Africa are only represented by a few stations. It is evident, therefore, that the value 760 mm. is too high. FRITSCHE [1906, p. 51] gives the mean value for the rainfall over the Mediterranean countries to be 675 mm. annually.

In spite of this, PÜTTER [1909, p. 110] employs FISCHER's value 760 mm. in calculating the amount of river-water which is added to the Mediterranean, starting from the hypothesis that $^1/_3$rd of the quantity of rain is carried down by the rivers; his result is ca. 2000 km^3. annually. As already indicated earlier by WOEIKOW [1885], the factor $^1/_3$rd for the drainage, which applies approximately for the rivers of Middle Europe, cannot be employed for regions with a smaller and periodic rainfall, and WOEIKOW gives the

[1] In reality, the mean value of the salinity in the total mass of inflowing water is somewhat greater than 36.1 ‰, owing to mixing with the outflowing water, just as 38.0 ‰ is possibly too high for the Mediterranean water which has become somewhat diluted during its outflow. The difference $S_u - S_i$ is in this case somewhat less than that given above, and the difference between inflow and outflow is still less than 5 per cent. of the inflow.

factor 1/4th as a more probable value. There is no doubt, however, that this also gives too high a value for the amount of river-water. The areas of the regions which drain into the Mediterranean are as follows:

	Penck [1894 I, p. 189]	Fritsche [1906, p. 47]
Europe	3.0×10^6 km².	2.954×10^6 km².
Asia	0.7 — —	0.705 — —
Africa	3.9 — —	3.522 — —

Thus almost the half belongs to Africa and in this the Nile region, for which according to Fritsche [p. 53] the drainage factor is only 4.26 %, occupies alone over 2.8×10^6 km².

It is evident, therefore, that such a method of calculating cannot give even an approximately correct value for the amount of river-water brought down to the Mediterranean, and I endeavoured therefore to ascertain this on the basis of the data regarding the amount of water carried down by the more important rivers. In this calculation I made use mainly of the values given by Fritsche in his excellent work above-cited. The result arrived at is, that the total amount of river-water amounts to ca. 900 km³. yearly; later, I found that a similar calculation had already been made for the Mediterranean by Sir John Murray [1887, p. 67], who has given almost the same value, namely, 942 km³. (226 cubic miles).

An estimate of the total amount of rainfall is also attended with considerable difficulties. It is well-known, that the rainfall increases with the height up to a certain height above the sea, and an estimate of the fall over the Mediterranean should therefore only take account of the low-lying stations of the coast, but even these probably give results which are greater than the rainfall over the sea itself. Greatest importance must naturally be ascribed to the amounts measured on the islands in the Mediterranean, but I have only been able to obtain the records from a few of these. I hope later to be able to return to the whole question of the exchange of water in the Mediterranean and especially in its different parts, but meantime I may give here some results.

For the Black Sea, Spindler [1898] gives the mean value of the rainfall as 577 mm., a value which is probably a little too high, owing to the fact, that the high records for the rainfall in the Caucasus are ascribed too much weight. As the average for 10—14 years of the Grecian observations on the islands Andros, Cythera, Naxos, Santorin and Syra in the Aegean Sea, we find the value 520 mm. The amount of rainfall over the Levant is only imperfectly known, but is hardly as much as 400 mm. on the average. For the Balearic Sea it is about 500 mm. and perhaps somewhat greater over the Tyrrhenian Sea, whilst for the Adriatic Sea it reaches 700—800 mm.[1]

For the whole of the Mediterranean region (including the Black Sea) this gives a value, which lies with a fair amount of certainty between 400 and 500 mm.; if we take the value as 450 ± 50 mm., this gives 1335 ± 150 km³. as the area is 2.968×10^6 km².

As the total amount of river-water, as determined above, is 900 km³. within the limits $\pm$ 100 km³., we thus have, that the total amount of fresh water which is added to the Mediterranean is $1335 \pm 150 + 900 \pm 100$, thus:

$$F = 2235 \pm 250 \text{ km}^3.$$

With regard to the evaporation, the calculation is much more uncertain than for the rainfall. We have not a few determinations of the evaporation at different places in the Mediterranean, but the mutual agreement is not satisfactory. The best agreement is found between the observations made at the Algiers

[1] In addition to the data for the rainfall given by Hann in his "Handbuch der Klimatologie" III, Stutgard 1897, I have also made use of "Atlas climatologique de l'Empire de Russie", St. Pétersbourg 1900, for the Aegean Sea the rainfall observations published since 1894 in "Annales de l'Observatoire national d'Athènes" III—V. "Summary of the Weather in Egypt, the Sudan, and the surrounding region" gives monthly averages for the rainfall at several stations in the Eastern Mediterranean. Further, Angot [1883, 1895, 1897], Thevenet [1896]. For the Spanish Mediterranean coast we have records for recent years in the "Resumen de las observaciones meteorológicas effectuadas en la peninsula y alguna de sus islas adyacentes", published by the Meteorological Institute of Madrid since 1906.

coastal stations [THEVENET 1896, p. 53] which give ca. 1400 mm. as the mean of the yearly evaporation at 9 stations. In the above-cited work published by the Meteorological Institute of Madrid, we find data after 1906 for the evaporation at 8 stations on the Balearic Isles and along the Mediterranean coast from Villanueva to Melilla; from these the mean is found to be 1645 mm., but the separate values are very variable. The same applies to the data given in the "Meteorological Report, Cairo" and "Summary of the Weather in Egypt, the Sudan etc." for 4 stations from Alexandria to El Arish, which give the mean value 1425 mm., for Candia 1480 mm. (observations only for 1909 and 1910). For Athens ÉGINITIS [1896, p. 207] gives the value 2040 mm. Older data [FISCHER 1879] give for Palermo ca. 1500, for Leghorn 1770 mm., [FINES 1883] for Perpignan 1650 mm.

These values cannot however be used directly for the evaporation from the Mediterranean, as this is undoubtedly less than at the coastal stations, partly because the atmosphere over the sea is damper, partly because the values given apply to the evaporation from freshwater. On the other hand, the results have probably all been derived from experiments, in which the evaporimeter has been sheltered from direct sunshine, and are thus less than the evaporation in the open.

Regarding the relation between the evaporation in the open and in the shade, we have only a few reliable determinations, as such experiments when made with an ordinary evaporimeter give far too high results for the evaporation in the sun, owing to the water becoming greatly heated. From experiments carried out at Azino (Japan) OKADA [1903] found, that the evaporation from freshwater was in summer somewhat above, in winter somewhat below double the evaporation in the shade. Earlier experiments of BROUN [HANN 1906] on the evaporation from large masses of sea-water, carried out in South India, gave a yearly evaporation of 2320 mm. or almost $2^1/_2$ times as great as the evaporation in the shade.

The evaporation from seawater is dependent, further, on the salinity; the experiments made agree in showing, that the evaporation from seawater is less than from freshwater, but the agreement ceases, as soon as there is a question of the relation between the two dimensions. MAZELLE [1898, p. 280] from a long series of experiments made at Trieste on seawater with a salinity of 37.3 ‰ finds, that the evaporation from this is only 70 % under slight evaporation, when the evaporation is greater up to 91 % and as mean of the whole series 81 % of the evaporation from freshwater, whilst DIEULAFAIT [1883] found a reduction of only 3.5 %. OKADA'S experiments with seawater of a lower salinity (ca. 27 ‰) give the result, in contrast to MAZELLE'S, that the relation between the evaporation from salt and fresh water decreases with increasing temperature (evaporation) and at 15° or more is constantly 95 %. From experiments made at Athens ÉGINITIS [1896, p. 208] gives a value which is 8 % less than for freshwater.

If we except MAZELLE'S results, these values for the evaporation of seawater are somewhat greater than we should expect. From the lowering of the freezing-point of seawater with S ‰ salt WITTING [1908, p. 173] has calculated, that the reduction in the pressure of aqueous vapour is

$$\frac{f-f'}{f} = 0.000537 \cdot S$$

where f and f' are the pressure of aqueous vapour over respectively pure water and saltwater; for Mediterranean water this gives $f - f' = 0.02 \cdot f$. As the evaporation can be expressed by the formula

$$E = C(e_0 - e)$$

where e is the pressure of aqueous vapour in the atmosphere, e_0 the aqueous pressure of the evaporating liquid at the existing temperature and C a constant depending on the outer conditions (air temperature, air pressure and velocity of the wind), we obtain, when the evaporation for freshwater and Mediterranean water under the same conditions is respectively E and E', and e'_0 gives the pressure of aqueous vapour of seawater:

$$\frac{E'}{E} = \frac{C(e'_0 - e)}{C(e_0 - e)} = \frac{0.98 - \frac{e}{e_0}}{1 - \frac{e}{e_0}}.$$

We see from this, that under a slight evaporation ($e_0 - e$ small) the relation between E' and E is less than under a greater amount of evaporation (e_0 large in proportion to e), and that the value $E' : E$ increases with the evaporation and approaches to the limiting value 0.98 when the evaporation takes place in an absolutely dry atmosphere. Theoretically, therefore, MAZELLE's experimental results seem to give the most reliable values for the dependency between the evaporation from seawater and from freshwater.

Even if the above-cited observations on the evaporation at stations along the coasts of the Mediterranean were directly comparable, which is probably far from being the case, it is evident from the above discussion, that we are not able on the basis of these to give absolute values for the evaporation from the Mediterranean within fairly reasonable limits; the uncertainty in the determination of the relation between the evaporation in the open and in the shade and between seawater and freshwater is too great and our knowledge of the relation between the evaporation at the coast and in open sea is especially all too insufficient for this purpose.

The older, somewhat hypothetical values for the evaporation from the Mediterranean also permit of a considerable amount of latitude, namely from less than 1 to over 3 m. yearly. The first value was already given by HALLEY [1687, p. 367], who uses it in a calculation of the influence of the different factors on the exchange of water in the Mediterranean (drainage from rivers being estimated at 1827 million tons daily or ca. 670 km³. yearly), whilst FISCHER [1885, p. 415] takes the value to be over 3 m. Both of these values probably differ by an equal amount from the actual and it is in any case certain, that the latter value is far too high.[1] BRÜCKNER [1905, p. 442] estimates the mean value of the evaporation from the surface of the sea between 30° and 40° N. L. to be 100 cm., between 40° and 50° to be 70 cm.

After I had arrived at the conclusion, from a consideration of the total amount of solar radiation and the annual exchange of heat in the Mediterranean (see footnote), that the yearly amount of water evaporated lies between the limits 150 and 200 cm., a work appeared by LÜTGENS, which seems to confirm this result. LÜTGENS has determined the evaporation in open sea on a voyage in the Atlantic and gives as the result of his observations [1911, p. 425] the following means for the yearly evaporation.

50°—40° N. L.	95 cm.
40°—tropics	160 —
North-east tropics...	240 —
Equatorial region ...	115 —
South-east tropics...	225 —
30°—40° S. L.	140 —

As the evaporation over the Mediterranean is probably somewhat greater than over the Atlantic at the same latitude, and as the Levant, at least in summer so far as the winds are concerned, has almost the same character as the zone of the trade-winds [Seewarte 1905, p. 14], it is reasonable to conclude, from LÜTGENS' result, that the annual evaporation is over 150 cm., though scarcely greater than

[1] According to KNOTT [1902] the amount of heat which the sun radiates out yearly to a unit of area on the earth's surface is 13.4×10^4 cal. at 56° N. L., 28.5×10^4 at the equator and ca. 22×10^4 cal. at 33° N. L. If the mean value for the whole Mediterranean is taken to be 200,000 cal. and the heat of evaporation (at 20° C.) 592 cal., the whole of this amount of heat is only sufficient for the evaporation of a little less than 3.4 m. It is evident, however, that the whole of this amount of heat cannot be used for evaporation, a portion is at once reflected back from the surface, another portion is radiated out during the night to the atmosphere and lastly, in the course of the summer heat to the amount of ca. 70,000 cal. [KRÜMMEL 1907, p. 497] is accumulated in the water and is given off in winter to the atmosphere, only a small portion probably going to the formation of water-vapour.

It is probable, therefore, that the energy received from the sun is scarcely sufficient for the evaporation of more than 2 m. water. If the loss of heat by radiation and reflection is estimated at 20 % and if we estimate that the whole of the heat stored up in summer, 70,000 cal., is given off without any part being used for evaporation, we then obtain probably a lower limit for the amount of heat available for the formation of vapour, namely 200,000 — 40,000—70,000 = 90,000 cal., which is sufficient to transform a water-column of ca. 150 cm. to vapour.

200 cm. If, then, we take the mean value for the annual evaporation from the whole Mediterranean to be 175 cm., the error is probably not greater than $\pm$ 25 cm.

For the total evaporation we then have $E = 2968 \times 10^{13}$ (175 ± 25) cm^3.

$$E = 5194 \pm 742 \text{ km}^3.$$

and on inserting the values for F and E in the equation $0.05 \cdot I = E - F$ we have

$$0.05 \cdot I = 5194 - 2235 \pm 742 \pm 250 = 2859 \pm 992$$

$$\text{thus} \quad I = 59180 \text{ km}^3.$$

$$\text{and further,} \quad U = 56220 \text{ km}^3.$$

Under the most unfavourable combination of the errors in F and E the uncertainty in these values amounts to about $^1/_3$rd of the whole amount of water; the total yearly inflow thus lies between the limits 40 and 80 thousand cubic kilometers.

We may now endeavour to form some idea of the rapidity, with which this amount of water flows through the Straits of Gibraltar and we have already discussed the factors of periodic and unperiodic nature which influence this. The conditions of inflow, however, are undoubtedly further complicated from the fact, that the depth to which the surface-current goes also changes both periodically and unperiodically (in consequence of the wind's influence) and our knowledge of these changes is in fact infinitesimal.

The older observations made by Capt. Nares [1872] and Dr. Carpenter [1872, p. 565] from the "Shearwater" in 1871, allow a considerable amount of latitude for the situation of the boundary between the upper and under currents. On the other hand, the current-measurements made from the "Michael Sars" in the spring of 1910 paid special attention to this question, but as they only extended over a single day, chance outer causes may possibly have produced considerable divergence from the normal condition for the time of year, and in place of ascribing general weight to such a single determination, it is perhaps better to make use of the value for the thickness of the surface-current found from the salinity determinations, as we have several of these from different times of the year (Makaroff, Wolfenden, "Thor" in Febr. 1909, June and Sept. 1910).

Even on this basis, however, the result is somewhat uncertain; but if we take a section across the narrowest part of the Straits east of Tarifa, the mean value for the whole year of the thickness of the surface-current is probably not very far from 100 m. (perhaps almost slightly more). If now we call the breadth of the Straits b km., the cross-section area of the inflowing water is $a = b \cdot 10^3 \cdot 100 = b \cdot 10^5$ m^2., and if we call its mean velocity h, the inflowing quantity in the time dt is $a \cdot h \cdot dt$, and we have consequently:

$$I = \int_0^T a \cdot h \cdot dt$$

which for $T = 1$ year gives the total annual inflow.

If now we assume a constant as here, h is a function of evaporation, rainfall and difference of level, in addition to its having a daily period in consequence of the tidal movement. With regard to the dependence of the flow on the first-named factors we know only, that it is least in winter and increases in the course of the summer probably until September, but we are not able to state any regularity or law for this variation. On the other hand, the daily variation of the velocity can be expressed approximately as follows:

$$h = h_0 + H_0 \cdot \sin \frac{4 \pi t}{T_1}$$

where h_0 is a constant and H_0 is the maximum change of velocity of the surface-current produced by the tidal stream. The inflow in a diurnal period T_1 (more nearly 25 hours) is then:

$$i = \int_0^{T_1} a h dt = \int_0^{T_1} a h_0 dt + \int_0^{T_1} a H_0 \cdot \sin \frac{4\pi t}{T_1} dt = a h_0 T_1$$

which shows, that for a longer period of time the amount of inflowing water is independent of the tidal movement.[1]

Since we are unable to determine the annual and daily variation of the velocity of flow, we may restrict our attention to the average velocity for the current of 100 meters in thickness, which in 1 year carries 59,200 km³. of water through the Straits of Gibraltar into the Mediterranean. If this average velocity is called h cm./sec. and taking the breadth of the Straits as 14 km., we have

$$h \cdot 14 \cdot 10^5 \cdot 10000 \cdot 60^2 \cdot 24 \cdot 365 = 59200 \cdot 10^{15}$$

from which $h = 134$ cm./sec. or approximately 2.6 miles per hour.

This value is probably somewhat too high, owing to the fact, that the average for the thickness of the ingoing current at Tarifa is over 100 m.; the uncertainty in the value for the velocity is however still greater than in the value for I and may amount to about 50 %.

When the water-masses have passed through the narrowest part of the Straits, the thickness decreases as they spread out over the Alboran Sea, and we have already seen, that the distribution of the Atlantic water in the section Cape de Gata—Oran is very different in the different seasons. Thus, in February 1909 far salter water was found in the northern than in the southern part, with consequently a considerable difference in density, as can be seen from the accompanying Table, which shows the averages for intervals of 25 m.

d.	St. 52	St. 53	St. 54
0— 25	1.02741	1.02809	1.02830
25— 50	425	295	35
50— 75	485	465	47
75—100	66	605	66
100—125	1.028145	75	805
125—150	145	75	805
150—175	625	87	90
175—200	82	87	90
0—200	1.027964	1.028587	1.028649

If we now consider a plane in which the pressure is p, lying 20000 cm. below the surface at St. 54, its depth h_{52} cm. if the water-masses were the same as at St. 52 will be determined by

$$p = h_{52} \cdot \rho_{52} \cdot g = 20000 \cdot \rho_{54} \cdot g \qquad \text{from which}$$

$$\frac{h_{52} - 20000}{20000} = \frac{\rho_{54} - \rho_{52}}{\rho_{52}}$$

where ρ_{52} and ρ_{54} are the mean values of the density from 0 to 200 m. If we insert the values for ρ_{54} and ρ_{52} we obtain

$$h_{52} - 20000 = 13.3 \text{ cm.}$$

and in the same way we find $h_{52} - h_{53} = 12.1$ cm.

As the masses of water below 200 m. are pretty uniform, there must be a difference of level at the 3 stations and at St. 52 the surface will lie 13.3 cm. and at St. 53 13.3 — 12.1 = 1.2 cm. higher than at St. 54. A particle in the surface at St. 52 would thus be influenced by a force which tends to move it

[1] In a preliminary report Dr. Hjort [1911, p. 75] gives a diagram showing the maximum and minimum inflow during the above-mentioned series of observations in the Straits of Gibraltar; the thickness of the inflowing layer is ca. 150 m. and its mean velocity ca. 75 cm./sec. at the maximum and — 15 cm. at the minimum inflow. With the same letters as above we then have

$$h_0 + H_0 = 75; \quad h_0 - H_0 = -15 \qquad \text{from which } H_0 = 45 \text{ cm.}, \; h_0 = 30 \text{ cm.}$$

The same amount of water will thus be carried into the Mediterranean in 24 hours, if the velocity were constant and equal to 30 cm./sec.

towards the lower level northwards and that this movement is not carried out must in the first instance be ascribed to the deviating influence of the earth's rotation. Assuming that this is the only cause keeping the Atlantic water to the south side of the fairway (northerly winds will also contribute in the production of such a distribution, but that the wind alone has not produced this, is evident from the considerable extension downwards of the fresher water), we are able to form some conception of the difference in the velocity of the surface-water at the 3 stations.

Assuming provisionally that the water at St. 53 is at rest and that the velocity at the surface at St. 52 is v and that the water-particles move towards the east in straight lines parallel to the longitudinal direction of the channel, the normal to the direction of flow will then form an angle of ca. 25° with the direction of the section and the distance from St. 52 to St. 53 projected down upon the normal is then $l = 27.6 \cdot \cos 25 = 25$ miles or ca. 46 km. Assuming, further, that the density decreases evenly from St. 53 to St. 52 and that the velocity increases proportionally to the distance from St. 53, the line of intersection between the surface and a vertical plane through St. 53 at right angles to the direction of flow can then be considered a straight line, which forms an angle α with the horizontal plane determined by $\alpha = \frac{12.1}{4600000}$. A water-particle in the surface with mass m will then be influenced by a force $mg \cdot \text{sine}\, \alpha$ towards St. 53, whilst from the rotation of the earth it will be influenced by a force, directed to the right and at right angles to the direction of movement, and expressed by

$$C = 2mv \cdot \omega \cdot \text{sine}\, \varphi$$

where φ is the latitude and ω the angular velocity of the earth = 0.0000729 [Ekman 1906, p. 425]. The condition that the water-particle will continue its movement without change of direction is then

$$mg \cdot \text{sine}\, \alpha \cdot \cos \alpha = 2mv \cdot \omega \cdot \text{sine}\, \varphi$$

or $$g\alpha = 2v \cdot \omega \cdot \text{sine}\, \varphi \qquad \text{from which}$$

$$v = \frac{g\alpha}{2\omega \cdot \text{sine}\, \varphi}$$

If $\varphi = 36°$ and the values for g, α and ω are inserted, we obtain

$$v = 30 \text{ cm./sec.}$$

The same method of procedure can be used, even if we do not assume that the water-particles at St. 53 are at rest, if only their direction of movement is parallel to the direction of movement at St. 52; if then the velocity of the particles at the surface at St. 53 is v_{53} we have $v_{52} = v_{53} + 30$ cm./sec., whilst a similar calculation gives $v_{54} = v_{53} - 3$ cm./sec.

Whilst the velocity of the surface-current in the longitudinal direction of the channel is thus almost the same in the northern part, it increases greatly towards the coast of Africa, where it is about 30 cm./sec. (= 1.08 km./hour or ca. 14 miles in the 24 hours) greater than in the middle of the channel; the difference in the velocity decreases with increasing depth and to judge from the uniform density in a horizontal direction, it has disappeared at a depth of 200 m. In a similar manner we see, that the velocity in the upper current in the section from Cape Spartel to Cape Trafalgar is greater at the Morocco coast than at Spain in the month of September.

IX. The influence of the outflowing Mediterranean water in the Atlantic Ocean.

In 1684 already, Dr. Th. Smith put forward the suggestion, that an undercurrent flowed through the Straits of Gibraltar from the Mediterranean into the Atlantic. This hypothesis gained some adherents but also raised a great deal of opposition and nothing of any value towards the solution of the question appeared until Dumont d'Urville showed in 1826, that the temperature in the deep water of Cadiz Bay was considerably higher than at the same depth in the other parts of the Atlantic. The final proof of the existence of this undercurrent was given in 1870, when Carpenter showed, that not only the temperature but also the salinity was higher in the deeper water of Cadiz Bay than in the Atlantic, and that both the temperature and salinity approximated to the values found in the deep water of the Western Mediterranean.

This indirect proof for the existence of the undercurrent must be considered as far more decisive than the direct current-measurements made by Carpenter and later investigators and which probably have all been bound with great difficulties owing to the fact, that the surface-current runs in a contrary direction with a considerable velocity. Even if these current-observations are otherwise reliable, they are yet too few in number to give us information regarding the periodic and unperiodic variations in the extent and velocity of the undercurrent.

We have seen above, that the quantity of water which the undercurrent carries out into the Atlantic is ca. 56,000 cubic km. yearly, and as this quantity of water is not much less than the inflowing it is evident, that the undercurrent must also flow with a considerable velocity. We have seen, further, that the outflowing masses of water become somewhat mixed with Atlantic water already off Cape Spartel, so that the greater part has a salinity which is less than 38 ‰; as, now, the thickness of the undercurrent becomes less in consequence of the fact, that the depth in the channel through which it flows still decreases somewhat towards the west, we are probably right in assuming that the salinity of the outflowing water is below 38 ‰ when it has passed the shallowest part of the threshold between the Mediterranean and Cadiz Bay.

After passing over this threshold the outflowing water does not at once tend in a westerly direction into greater depths; from Sect. 22 and 23 (Pl. IX), which lie at the same place — south-west from Cadiz — we see, that both in February and June the saltest water bends to the north-west up towards the south coast of Portugal and keeps to the northern slope of Cadiz Bay. There is no doubt, that this is due to the deflection caused by the earth's rotation and we may conclude, therefore, that the salt water here in Cadiz Bay still flows with a considerable velocity.

The distribution of the outflowing water in the two sections is almost exactly the same; at St. 66 and St. 92 the salinity at the bottom is almost 37 ‰, whilst at the deeper stations 65 and 91 it is below 36.5, in winter even but little above 36 ‰. As the Atlantic water has its maximum for temperature and salinity at the surface, the mixing of the bottom-water with the Mediterranean water is shown in a very characteristic manner in both sections by a wedge-shaped minimum for temperature and salinity, which is situated to some extent parallel with the bottom.

Whilst the maximum salinity in the bottom-water had the same value both in February and June, about 37 ‰, there is some difference in the temperature, this being somewhat higher in June (at St. 92 ca. 0.6°, at St. 91 even over 1° higher than in February). The essential difference is, however, that the volume of the salt bottom-water is much greater in June; a comparison of the sections shows, that the transverse area of the water masses which have a salinity greater than 36 ‰ is almost twice what it

was in February. As we have no reason for assuming, that the velocity of the bottom-current in this section is greater in winter than in summer, we are permitted to conclude, that the outflow increases in the summer like the inflow. Thus the condition is, not that an inflow only takes place when the evaporation from the Mediterranean is greatest, but that the two opposing currents seem almost to have the same periodicity dependent on the season.

Although the salt bottom-water found at St. 66 and St. 92 has a high temperature, it has a considerably greater density than the water found in the centre of Cadiz Bay both at the same level and at the bottom, and if it were not subject to the deflecting influence of the earth's rotation, it would therefore at once move down towards the greater depths to the south-west. If the slope of the bottom were sufficiently well known, it might be possible from this and the known distribution of density, to form some conception of the difference in the velocity of the bottom-water at the two stations 65 and 66, in the same manner as earlier for the surface-water in the section Cape de Gata—Oran.

As the stations 66 and 92 lie nearer the Straits of Gibraltar than 65 and 91, we might perhaps be inclined to think, that the lower salinity of the bottom-water at the latter was due to its becoming mixed with Atlantic water during its movement downwards into the greater depths. This is not the case, however; at all the stations on the north side of the Bay as far as St. 87 at Cape St. Vincent there is a higher salinity than in the middle of Cadiz Bay. This shows, that the saltest masses of water always keep nearest to land and thus have the greatest velocity, and as the salinity gradient in the bottom-water is fairly great in the direction away from the coast, it is further evident, that the water-masses coming from the Mediterranean form a narrow and fairly well-defined belt along the coast.

As the velocity of the outermost portion of these water-masses gradually becomes reduced through friction with the Atlantic water, they sink downward on continued mixing with the latter, but this process is not continued to the greatest depths, as the product of mixing on the way downwards meets at some time with Atlantic water which has the same density as itself. When this occurs, it becomes enclosed at this depth as an intermediate layer, which is characterized by a maximum in salinity, and likewise, as far as to the northern part of the west coast of Portugal at any rate, by an intermediate maximum of temperature.

The two sections 24 and 25 (Pl. X), through the stations from the Straits of Gibraltar over Cadiz Bay along the coast of Portugal towards Brittany, show the distribution of this intermediate layer. At St. 87 (Sect. 25) near Cape St. Vincent the layer with a salinity over 36 ‰ has a thickness of at least 1000 m., and the maximum temperature is over 12°; at 1500 m. the salinity is still 36.29 ‰ and the temperature about 11°, which, compared with the temperature 4°—5° found in the western part of the Atlantic at this depth, shows what an enormous influence the Mediterranean water exercizes here on the deeper layers. In June 1910 masses of water with a salinity of 36 ‰ were still to be found up towards Cape Finisterre with a maximum about 1000 m., and the maximum of the temperature was a little over 11° and lay in 700—800 m.

During the movement northwards the temperature maximum gradually disappears and the salinity decreases but retains a maximum value which lies in about 1000 m.; this in June 1910 was seemingly over 35.7 ‰ as far as to the northernmost part of the Bay of Biscay, whilst in March 1909 it was a little under 35.6 ‰. The irregular conditions in the southern part of the sections show clearly what has been mentioned above, namely, that the Mediterranean water is less well-marked in the centre of Cadiz Bay than on the north coast; thus, the Atlantic water extends much deeper down and reveals itself in the sections by well-marked minima for the temperature and salinity, and we thus have the unexpected result, that for example at 600 m. both the temperature and salinity are lower in the middle of Cadiz Bay than at the northern part of the west coast of Portugal.

It was already apparent from the investigations of the "Challenger" Expedition, that the outflowing

water from the Mediterranean exercized great influence on the salinity and especially the temperature in the eastern part of the Atlantic down to depths of 2000 m. [e. g. Buchan 1895], and during a cruise with the "Thor" in 1905 quite distinct traces of the Mediterranean water were discovered by me [1907, p. 21] in the northern part of the Bay of Biscay and south-west of Ireland, from, namely, a relatively high temperature and an intermediate maximum in salinity in depths about 1000 m. During the cruise of the "Thor" in the summer of 1906 this was further confirmed by a series of stations from the south-eastern part of the Bay of Biscay up to south-west Ireland.

The results of these observations are given in Sect. 26, which shows a maximum in the salinity about 1000 m.; the absolute value of the maximum is greatest in the south-eastern part in the Fosse de Cape Breton, where it is ca. 35.8 ‰; from there the maximum decreases slowly towards the north-west and is 35.64 ‰ at 9°—10° W. L. (between Ireland and Cape Finisterre). As the salinity is thus greatest in the south-eastern part of the Bay of Biscay, it is seen, that the salt intermediate masses of water must bend towards the east along the north coast of Spain and only move towards the north-west after circulating in the Bay of Biscay.

At 12° W. and 49°—50° N. the maximum value is 35.55 ‰ and is constantly found in 1000 m. both in June 1905 and June 1906 and even to the west of Ireland, at 51.5° N., we find 35.52 ‰ at 800 m. The reason why the 35.5 isohaline in Sect. 26 is not continued to the northern part is, that we find here a bight extending from the depths of the Atlantic up to the west of Ireland and the conditions are analogous to what we found in Cadiz Bay, namely, that the saltest masses of water keep to the right side of the bight; in the middle however there is also a distinct maximum at 1000 m., but its value is only 35.44 ‰. Further to the south-west, at St. 66 (1906), the salinity maximum has completely disappeared and in 1000 m. we only find 35.34 ‰,

Although the salinity in the intermediate layer about 1000 m. varies but little with the place, we are able to notice some variation with the time of year. Thus, at St. 68 (1906) the maximum value has fallen 0.1 ‰ from June to September, but, as mentioned above, the value at the stations from Cape Finisterre to Brittany is somewhat greater in June 1910 than in March 1909; in September 1910 further it is somewhat greater than in June, which is probably connected with the periodicity in the outflow from the Mediterranean.

I have pointed out earlier [1907 p. 22], that the reason why the warm Atlantic water in the Rockall depression has a much greater volume than in the sea west of Rockall, is possibly to be found in a continuation of the Mediterranean water as an intermediate layer round to the west of the Porcupine Bank; but by gradual mixing with water-masses of lower salinity on the way this continuation loses its characteristic maximum of salinity before it reaches the Rockall depression. Dr. Brennecke, who also found the Mediterranean water in the Bay of Biscay during the "Planet" Expedition in 1906, remarks in a reference[1] to my work, that this conclusion is somewhat doubtful. As water-masses distinctly showing the influence of Mediterranean water are found south of the Porcupine Bank in movement towards the west and as there is also no doubt, that the water-masses west of the Bank in depths of 1000 m. are carried up through the Rockall depression, it is difficult to understand, what Dr. Brennecke imagines will become of these water-masses if they do not move northwards into the Rockall depression.

We have but few observations from the bottom-water of the Bay of Biscay; at St. 190 (1906), however, the observations at 2000 m. still show a temperature of 4.60° and salinity of 35.08 ‰, respectively 1° and over 0.1 ‰ higher than at St. 68 (1906) further to the west, so that the Mediterranean water in the Bay of Biscay is still appreciable at depths over 2000 m. At 3500 m. for the same two stations the values are very nearly the same; the temperature is 2.6°—2.7° and the salinity 34.97 and 34.94 ‰ respectively. In conjunction with our earlier observations in the northern part of the Atlantic this shows,

[1] Annalen der Hydrographie etc. 35, p. 513. 1907.

that the salinity of the bottom-water of the Atlantic is a little under 35 ‰ and not, as generally believed formerly, 35.2—35.3 ‰.

During the cruise of the "Thor" in 1906 about 100 bottles were thrown overboard to the south-west of Ireland and in the Bay of Biscay in order to determine the direction and strength of the surface-currents. They were thrown out in groups of 25, but only 8 have been returned; of these 1 has gone eastwards to the north coast of Brittany, whilst the remainder were found in the south-west of France and in the north of Spain, and 1 has continued southwards to be taken on the coast of Portugal at 40° N. L. The drift of these bottles has thus confirmed the results obtained earlier by the PRINCE of MONACO, HAUTREUX and BÉNARD, namely, that there is an anticyclonic movement in the Bay of Biscay, which is continued to the south along the coast of Portugal. As our information refers only to such a small number of the bottles thrown out, I shall not discuss their drift in detail, but the necessary data for the elucidation of the latter is given in the Table below for the sake of comparison with the earlier results.

Bottle	Thrown out			Found	
No.	Date	N. L.	W. L.	Date	Place
10	2. IX. 06	48° 04′	12° 40′	17. IV. 07	40° 02′ N. 8° 57′ W. Costa da Leirosa. Portugal.
27	3. " "	47° 52′	13° 10′	4. X. "	Lit-et-Mixe. Landes. France.
44	3. " "	" "	" "	18. IV. "	Sopelana. Bilbao. Spain.
51	4. " "	49° 22′	12° 52′	29. X. 06	Guissény. Finistèrre. France.
56	4. " "	" "	" "	14. II. 07	San Vincente de la Barquera. Santander. Spain.
90	11. " "	46° 54′	6° 22′	3. I. "	Vieux-Boucau. Landes. France.
94	11. " "	" "	" "	14. II. "	Guetaria. Guipuzcoa. Spain.
99	11. " "	" "	" "	14. II. "	Anglet, entre Biarritz et l'embouchure de l'Adour. France.

As the movement at the surface in the northernmost part of the Bay of Biscay is directed towards the south-east, in the southern part towards the west and then south along the Iberian Peninsula, and as probably the bottom-water also moves from north to south, we see, that the intermediate layer with the Mediterranean water moves in an opposite direction to the surface-water and in part also to the bottom-water. Where the transition lies between the mutually opposed movements in the surface-layer and intermediate layer, we are not able to say, but to judge from the distribution of the salinity, it is not deeper than 600 meters.

C. Résumé.

I. Historical summary.

The earliest temperature observations made in the Western Mediterranean by the French investigators (Saussure, Dumont d'Urville, Bérard, Aimé) in the years 1780—1845 gave already a correct picture in the main of the vertical distribution of temperature. The result of these observations, which were carried out after different principles, was that the temperature in great depths was constant and very nearly 13° C. The reason for the great difference between this temperature and the temperature in the depths of the Atlantic was also indicated, namely, that the Gibraltar threshold prevents an inflow of cold water from the depths of the Atlantic and consequently, that the temperature in the Mediterranean cannot become lower than the lowest value occurring at the surface.

The thickness of the surface-layer, in which the temperature varies in the course of the year, has received somewhat different estimates. Aimé, who studied both the daily and yearly fluctuations in temperature, indicates 350—400 m. as the boundary for any appreciable variation in temperature in the course of the year. From his observations at the surface between France and Algiers Aimé concludes, that the temperature in the bottom-layer has just the same value as the uppermost layer has in the coldest time of the year, and that the temperature of the bottom-water is thus determined by a sinking of the surface-water. Aimé also investigated the amount of air absorbed in the deeper layers and showed, that this amount was not very different from the amount in the surface-water.

In the Eastern Mediterranean some temperature observations were made by Spratt, who concluded that the temperature in deep water was constant just as in the western basin. Spratt's results were somewhat uncertain, however, and the absolute values differ considerably from those found later.

Admiral Smyth, who gave a detailed account of the currents in the surface-water of the Mediterranean was the first to collect water-samples from the deeper layers there; Wollaston's analyses of these, which showed for one sample a value of over 17 %, gave rise to the absurd hypothesis, that the bottom-layer consisted of a saturated saline solution.

Carpenter, who combined temperature observations and determination of the density, chlorine and oxygen with zoological investigations, gave the first complete picture of the hydrographical conditions and emphasized the importance of evaporation. Carpenter estimated the boundaries for the temperature variation in the surface-layer at ca. 200 m. in the western and about 400 m. in the eastern basin, and concluded in agreement with the earlier observers, that the temperature is constant in the bottom-layer, where only very small movements occur.

Carpenter's views have persisted practically unchanged, though Magnaghi found an intermediate minimum in the Tyrrhenian Sea and below this a maximum in the temperature; later Buchanan found an intermediate maximum in salinity in the northern part of the Balearic Sea. The conditions are thus in reality much more complicated than was earlier believed, but although these intermediate maxima

were pointed out by such prominent observers, they do not seem to have attracted any attention, possibly due to the fact, that the maximum differences are not much greater than the uncertainty of the methods.

Makaroff showed, that the salinity near the coast of Syria is constant down from the surface, and remarked, that there was a possibility of a sinking down of the surface-water there and thus of a renewal of the bottom-water.

In the Black Sea Spindler and Wrangell found, that there is an extensive bottom-layer containing hydrogen sulphide, with a temperature of ca. 9° and a salinity of ca. 22 ‰, which is separated by a temperature minimum from a surface-layer with a salinity of ca. 18 ‰. This fresher surface-layer prevents a vertical circulation from the surface and there is thus the possibility for the formation of sulphuretted hydrogen in the stagnant bottom-layer. Makaroff and Spindler also subjected the currents flowing into and out of the Black Sea to a quantitative investigation.

In the Sea of Marmora Spindler found a thin surface-layer coming from the Black Sea and an extensive bottom-layer with a salinity almost as great as that in the Aegean Sea (ca. 38.4 ‰) and a temperature of ca. 14°; in the latter, on the other hand, there is no sulphuretted hydrogen. The investigations made by Natterer in the Sea of Marmora almost at the same time gave the same distribution of temperature, but the results for the salinity are untrustworthy.

The investigations made by the "Pola" Expedition in the Eastern Mediterranean showed, that the temperature in the deep water just as in the Western Mediterranean was constant in a vertical direction and that all the values observed in the bottom-layer lay between 13.5° and 13.7°. In the Aegean Sea, however, lower values were found in the northern part than in the southern. On the other hand, the salinity observations in the Eastern Mediterranean showed greater variations from place to place; this, however, has not been confirmed by our investigations.

Whilst probably all the earlier observers have considered that the water in the great depths of the Mediterranean was stationary or only subject to extremely small movements, Thoulet took up the opposite standpoint. This is undoubtedly correct, but its basis seems to have been somewhat uncertain and to come mainly from errors of observation. On the other hand, the view advocated by Thoulet, that the composition of the Mediterranean water was so very different from that of oceanic water, that the Knudsen tables could not be used for it, has proved to be without foundation.

II. Results of the **Thor**'s investigations in 1908—09 and 1910.

It seemed improbable beforehand, that the extensive bottom-layer in the Mediterranean could have a constant temperature and salinity; in the case of the deeper layers, therefore, by means of control determinations of various kinds, special pains were taken to obtain the greatest possible accuracy. The error in the salinity determinations from great depths, which were made on board during the summer cruise, scarcely amounts to $\pm$ 0.03 ‰ in the absolute and $\pm$ 0.02 ‰ in the relative values. The limits of error for the temperatures at great depths may be set at 0.02°—0.03°. The uncertainty in the salinity determinations for the winter cruise, when the samples were analyzed after the end of the cruise, is possibly a little greater.

By a theoretical method I have shown, that when a column of water with constant salinity is cooled down from the surface, until it is in a condition of indifferent equilibrium, this does not mean a uniform temperature throughout, as has been believed hitherto; on the contrary, the temperature increases with the depth. For Mediterranean water this increase is represented in fig. 13 (p. 145) and it amounts to $^1/_2$° C. at a depth of 3000 m. In this case the density (at a pressure of one atmosphere) decreases downwards and at the depth indicated is 0.0001 lower than at the surface.

A column of water with constant salinity, in which the temperature is everywhere

determined by water sinking down from the surface, has therefore a temperature increasing with the depth, and the temperature gradient has precisely the dimension shown by curve I in fig. 13. If the temperature gradient is less than this, the column of water is in a condition of constant equilibrium; if, in this case also, the bottom-water has come from water which has sunk down from the surface, then this descent must have occurred at places where the upper layers had a lower temperature. A greater temperature gradient (numerically greater density gradient) shows, that the column of water is not in equilibrium; a descent from the upper and an ascent from the lower layers then take place.

As the most important result of our investigations in the Mediterranean we have found, that a bottom-layer with both constant salinity and uniform temperature does not exist; the extensive layer of water, for which this was supposed to be the case, consists in reality of two essentially different layers, separated by a temperature minimum.

In the Balearic Sea this temperature minimum lies at a depth of 800—1000 m., in the Tyrrhenian Sea about 2000 m. and in the Eastern Mediterranean as a rule between 1000 and 1500 m., but around this minimum there is only an extremely slight vertical variation for a distance of 500 to 1000 m. Below the temperature minimum we meet with the true bottom-water with constant salinity in a vertical direction and also, within the same natural region, in a horizontal direction. In agreement with what we might have expected, the temperature in this bottom-layer was not uniform but increased downwards; at the greatest depths the temperature gradient converges towards the calculated value.

The salinity and temperature increase upwards from the temperature minimum in deep water. In the Western Mediterranean both have an intermediate maximum, in the Balearic Sea at a depth which varies from 200—400 m., in the Tyrrhenian Sea on the whole somewhat deeper. Above this intermediate layer there is a less saline surface-layer, which is influenced by the inflowing Atlantic water (down to 200 m. in thickness); on the boundary between the latter and the intermediate layer there is a minimum in temperature arising from the cooling process of the preceding winter.

In the Ionian Sea there is likewise an intermediate maximum in the salinity about 300 m. and a fresher surface-layer, also separated sometimes by a temperature minimum. In the Levant the temperature minimum disappears; in the northern part the salinity steadily increases towards the surface, but in the southern part there is still a considerable surface-layer of Atlantic origin; in the neighbourhood of the surface, however, it is strongly concentrated as a consequence of evaporation.

In a horizontal direction, in the same horizontal section, the temperature and salinity decrease in the main from east to west. In the bottom-layer the temperature at the same level decreases from the Levant to the Ionian Sea by ca. 0.1°, from this to the Tyrrhenian Sea (depths of 2000 m. or more) by 0.4°, and from the latter to the Balearic Sea by 0.1°—0.2°. The summary charts on Pl. XI show for different depths the values within the different regions.

The primary cause of the horizontal circulation in the Mediterranean is the evaporation. As this is greater than the amount of water added by rainfall and rivers, the loss of water must be compensated for by an inflow of Atlantic water. This inflow keeps mainly to the north coast of Africa under the influence of the earth's rotation, but nevertheless sends offshoots up into the Balearic and Tyrrhenian Seas, so that the different current systems in the surface-layer are more or less influenced by Atlantic water.

In the central and northern parts of the Levant, where there is no intermediate minimum of salinity, and where the surface-water is strongly concentrated (over 39 ‰) a homohaline surface-layer is formed in winter. As the cooling process is not so strong, that this layer can sink down into the depths, it spreads out towards the west as an intermediate current, which under the influence of the earth's rotation forms cyclonic current systems in the various basins.

This intermediate current, which produces the characteristic division into layers in the western part of the Mediterranean, in the end carries back to the Atlantic the quantity of salt brought from there. The directions of movement in the intermediate layer and in the surface-layer are marked off on the summary-chart Pl. XI.

Extensive evaporation may lead to a vertical circulation in the neighbourhood of the surface in the water cooling down at night. It only obtains any great importance, however, during the cooling of winter, but for the greater part of the Mediterranean the vertical circulation is restricted to a surface-layer of very variable thickness. This is the case, for example, in the Black Sea and Sea of Marmora, the Levant, Ionian, Tyrrhenian and the southern part of the Balearic Sea. In the northern part of the Balearic Sea as also in the Ligurian Sea, on the other hand, cooling of the surface-water may produce vertical currents down to the greatest depths, by means of which the bottom-water is ventilated. The same process goes on in the Aegean and probably also in the southern part of the Adriatic, from which new bottom-water is transported to the Levant and Ionian Sea. As the bottom-water is very uniform in a horizontal direction, it must also be subject to active horizontal movements.

The annual variation of temperature in the surface-water is least in the southern part and increases northwards, especially in the Eastern Mediterranean. Whereas it is about 10° C at Africa, it increases to about 20° in the Black Sea. In the intermediate layer there is a by no means unimportant, annual variation (see figs. 14, 15 and 16); the values are higher in winter than in summer. In the bottom-water there is extremely little variation in the course of the year.

The annual exchange of heat cannot be definitely given, as the amount of heat accumulated had not reached its maximum at the time when the observations were made; off Barcelona (St. 210), where the inflow probably has little influence, 60,000 cal. give a lower limit for the annual exchange of heat.

The annual variation in the salinity is extremely small for the bottom-water; in the intermediate layer there is an appreciable variation with a maximum in winter. In the surface-water the variation is very irregular; in the central and northern parts of the Balearic Sea, for example, the salinity is greatest in spring and decreases in the course of the summer, whilst in the Ionian Sea and the Levant it undoubtedly increases in the course of the summer.

A quantitative estimate of the total, annual exchange of water in the Mediterranean gives ca. 2,200 km^3. for the added quantity of fresh water (rainfall and river-water) and 5,200 km^3. for the loss due to evaporation. As compensation for this loss of water of 3,000 km^3., there is an inflow of ca. 59,200 km^3. through the Straits of Gibraltar (an amount of water which, distributed over the whole surface of the Mediterranean, would raise its level by a height of 20 m.), whilst ca. 56,200 km^3. are at the same time carried out by the under-current into the Atlantic, where it keeps mainly along the coast of Europe; from the presence of a maximum in the salinity at depths about 1000 m. it can be followed with certainty to the waters south-west of Ireland.

D. Bibliography.

The following abbreviations have been used.

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C. R.: Comptes rendus hebdomadaires des séances de l'académie des sciences. Paris.
M. Z.: Meteorologische Zeitschrift (Zeitschrift der k. k. österreichischen Gesellschaft für Meteorologie) Braunschweig.
Phil. Trans.: Philosophical Transactions of the Royal Society of London.
P. M.: A. Petermanns Mitteilungen aus Justus Perthes' geographischer Anstalt, herausgegeben von A. Supan.
P. R. S. E.: Proceedings of the Royal Society of Edingburgh.
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STATIONS AND SECTIONS.

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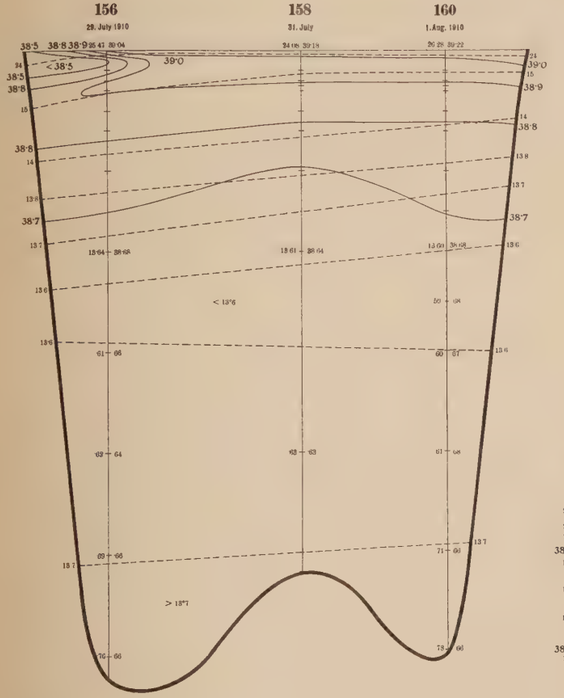

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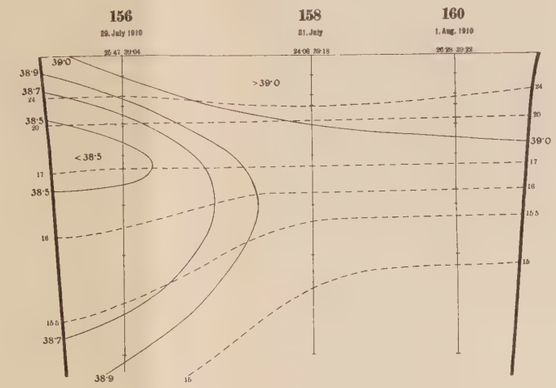

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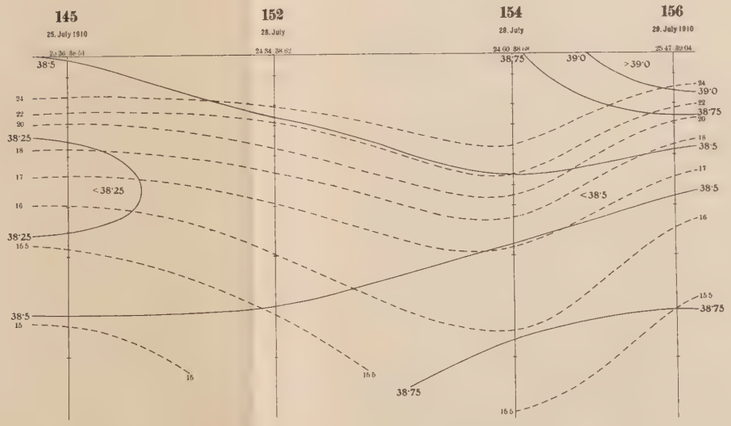

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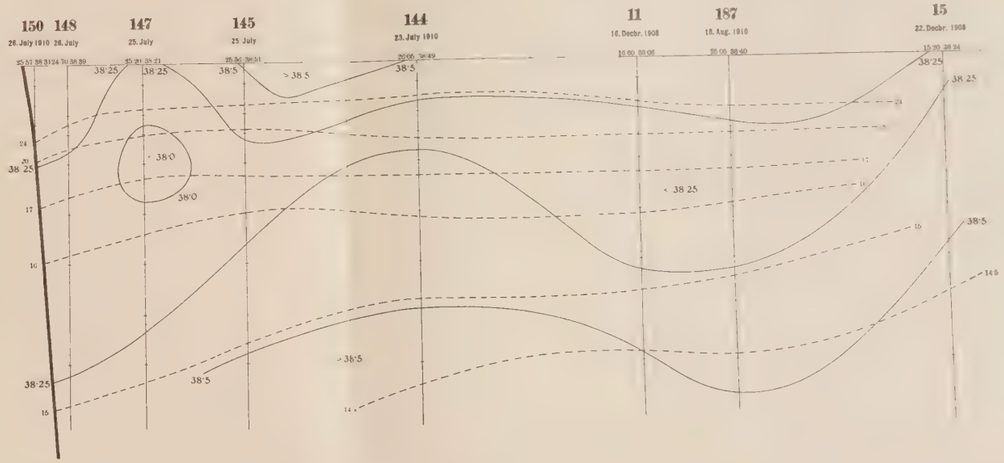

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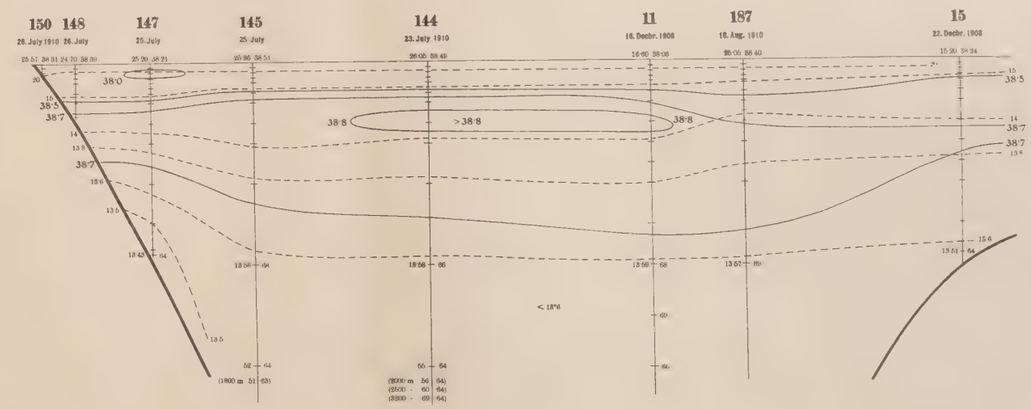


Vertical scale for Sect. 1 A, 2 A, 3 A

Vertical scale for Sect. 1 and 3

Salinity

Temperature

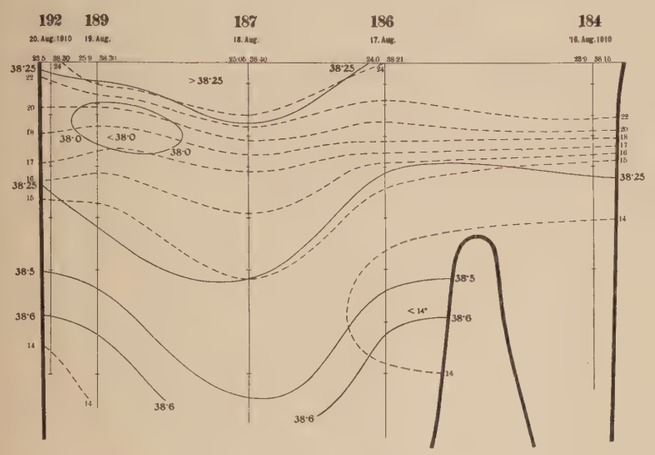
1 mm = 5 km

0 100 200 300 400 500 600 700 800 900 1000 km.

1 : 5 000 000

Cam. Aschehoug & Co's Bogtr. Anstalt

4 A



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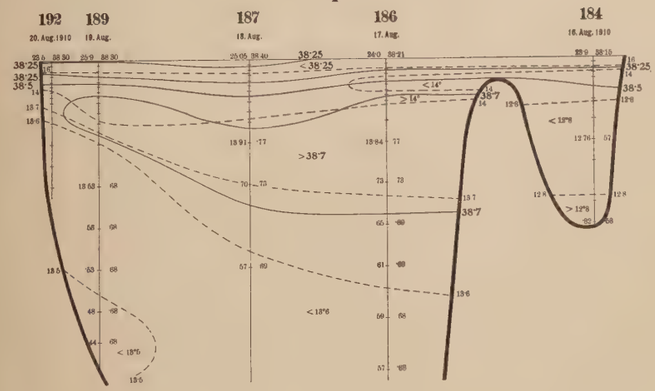

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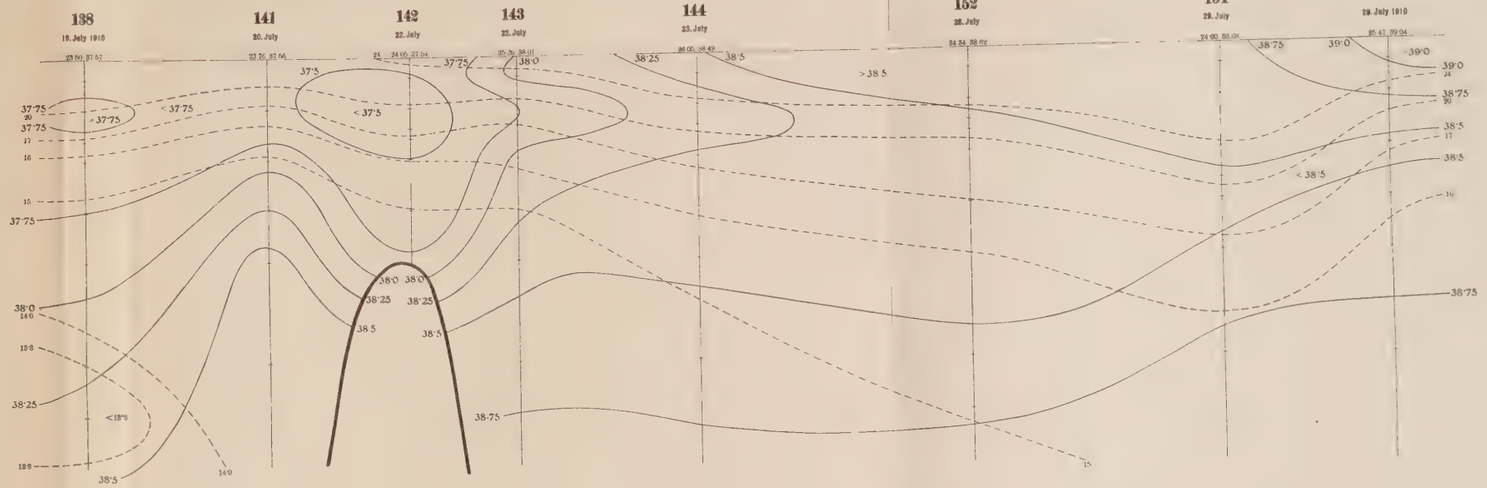

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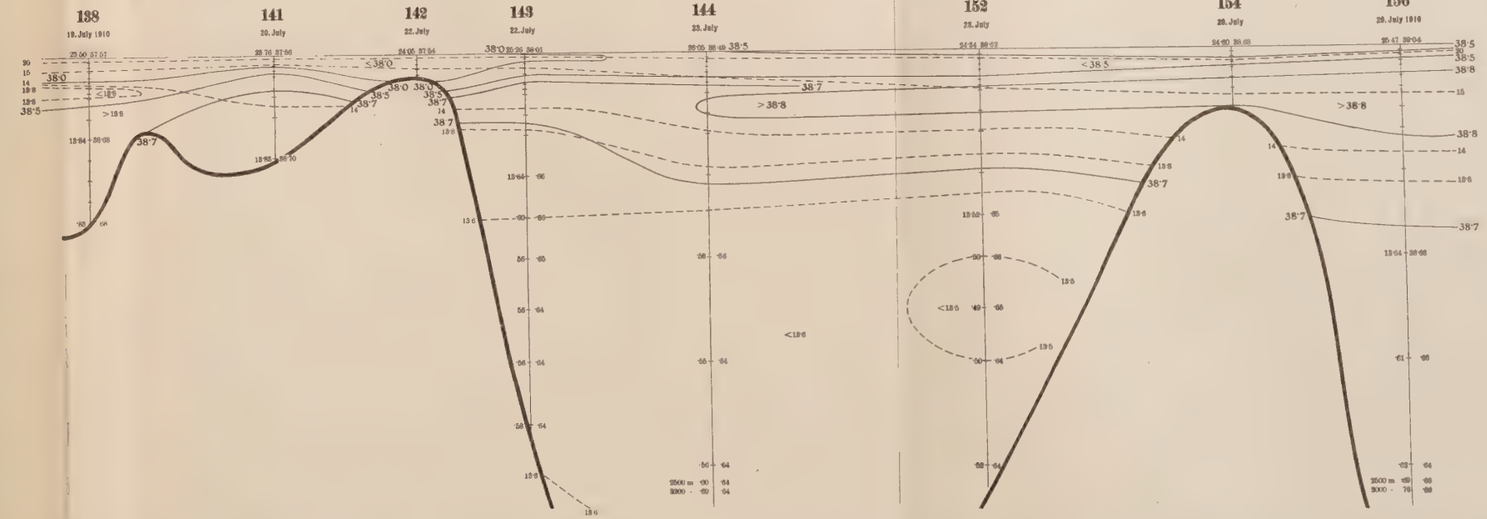


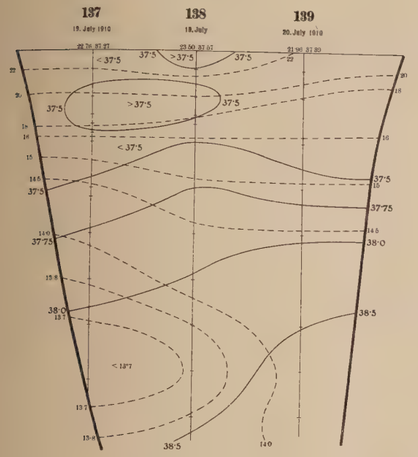
1 mm = 5 km

0 100 200 300 400 500 600 700 800 900 1000 km

1 : 5000000

Carl Aller's Etabl. Bogtr. Andralt

6 A



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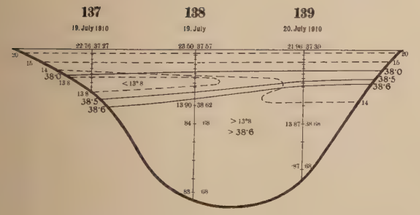

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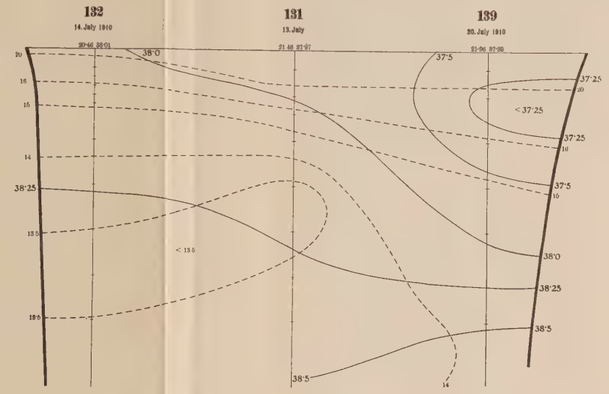

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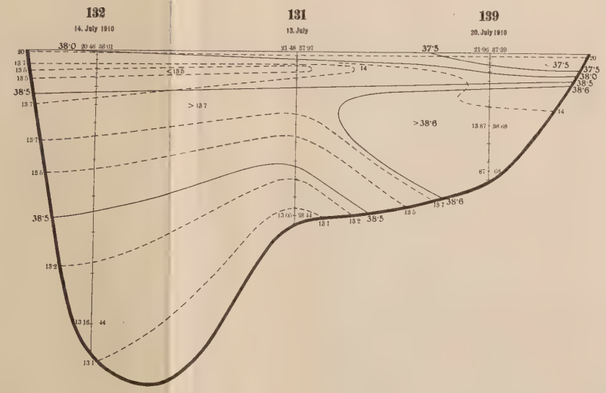

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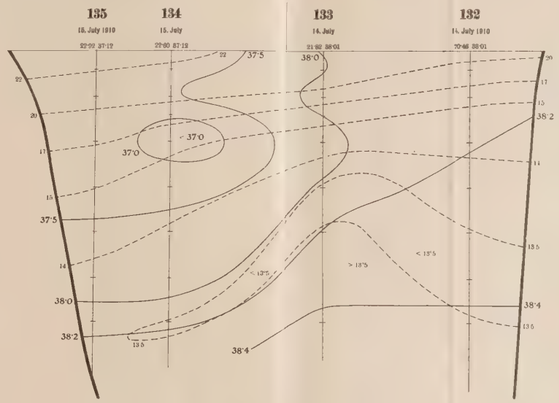

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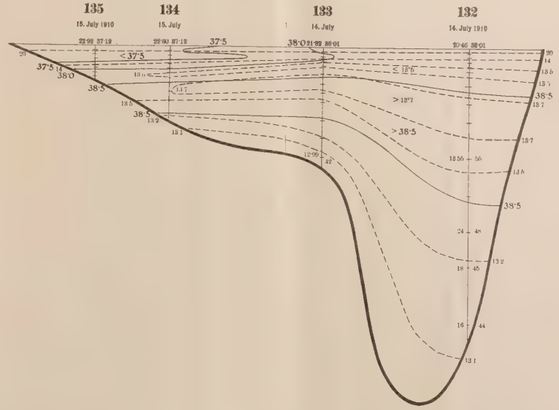

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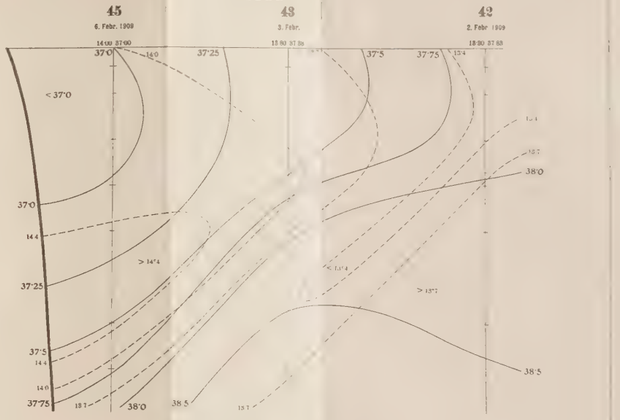

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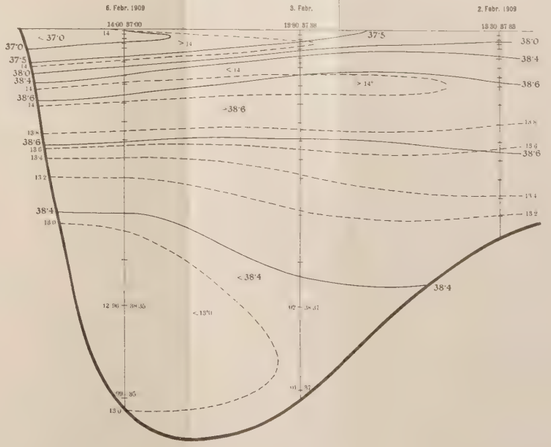

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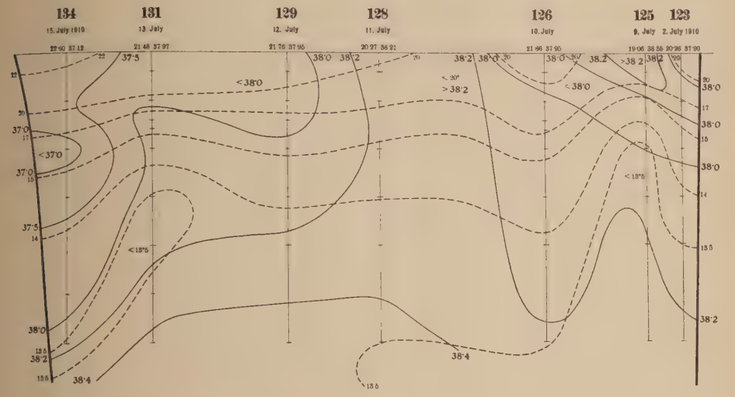

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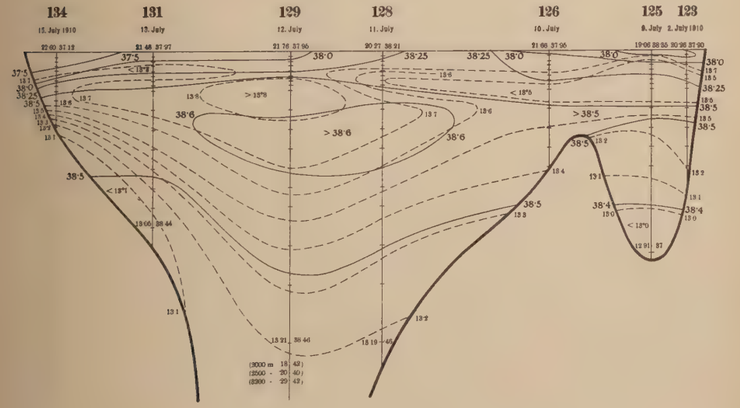

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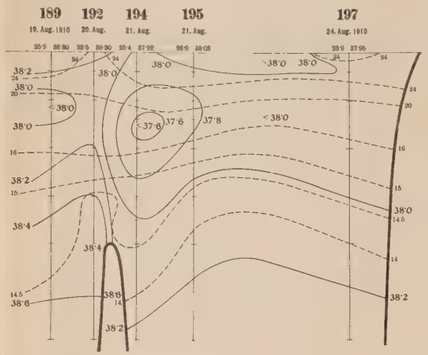

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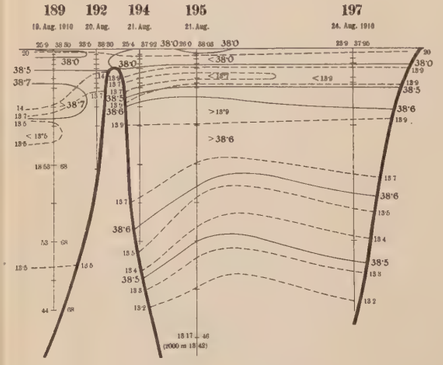

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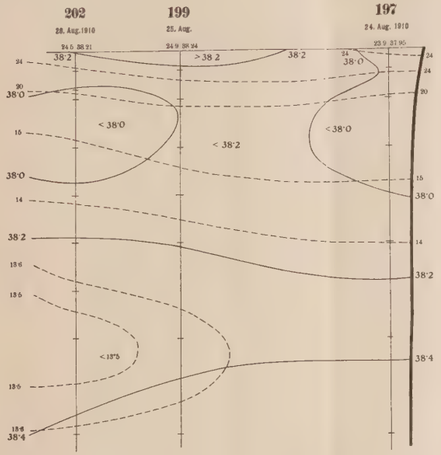

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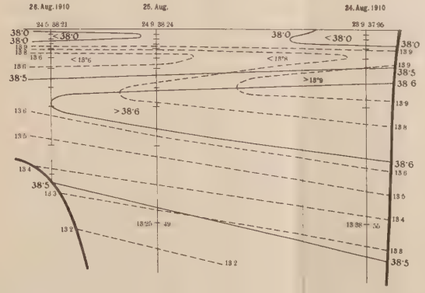

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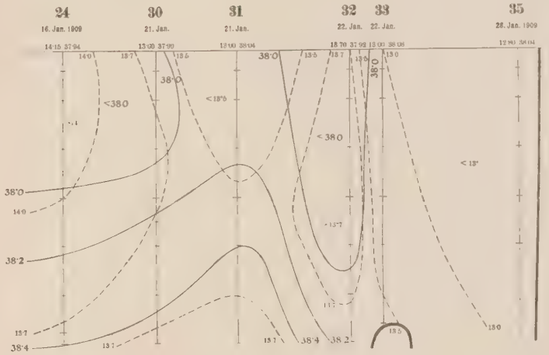

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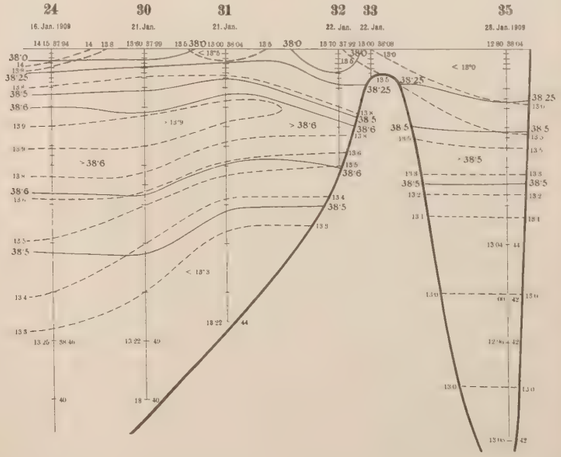

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0 100 200 300 400 500 600 700 800 900 1000 km

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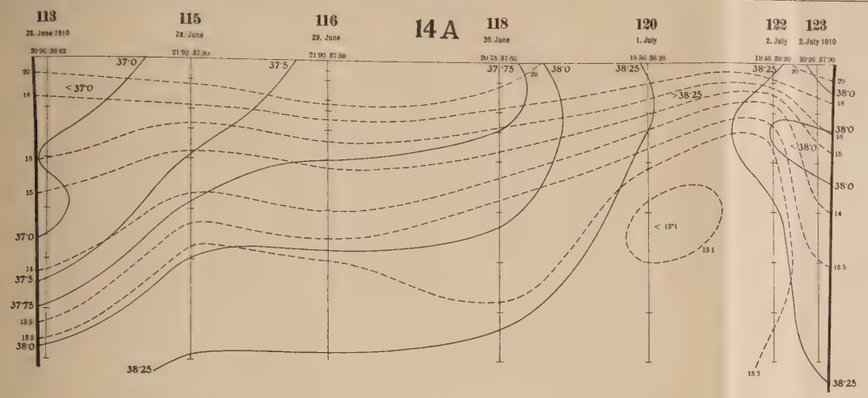

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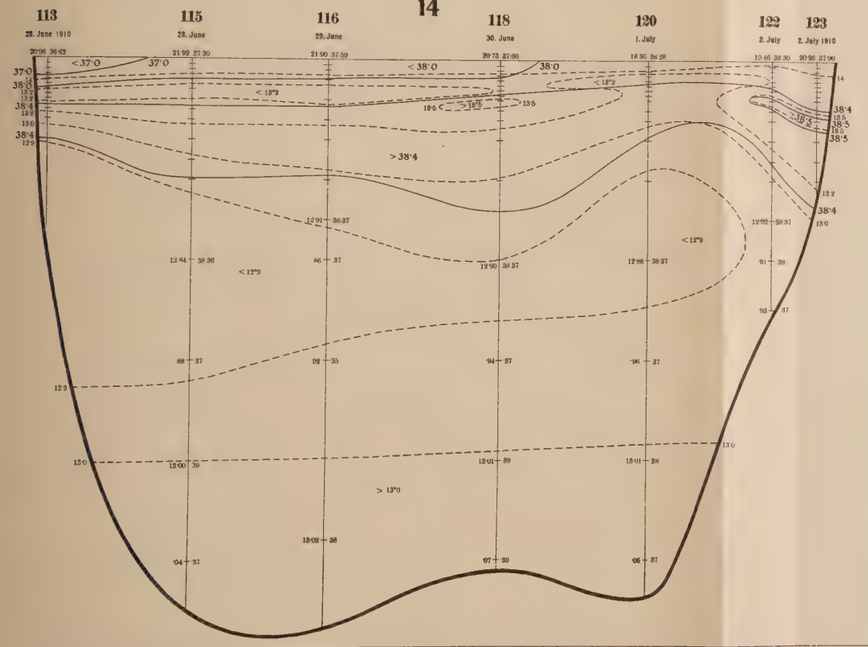

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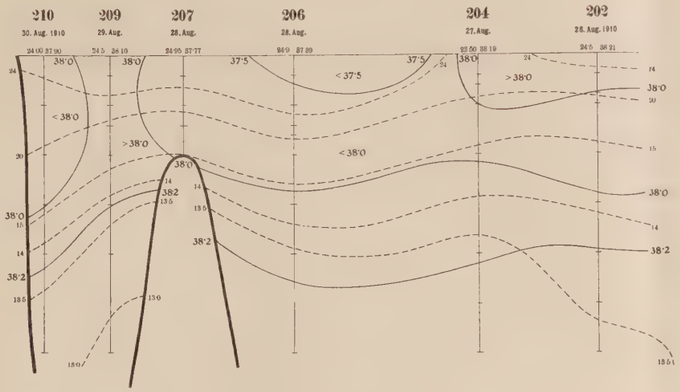

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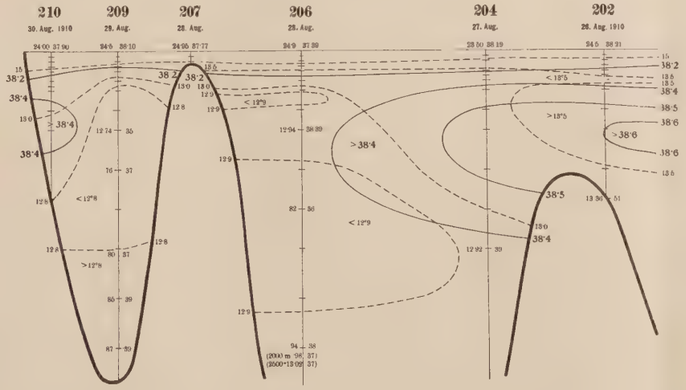

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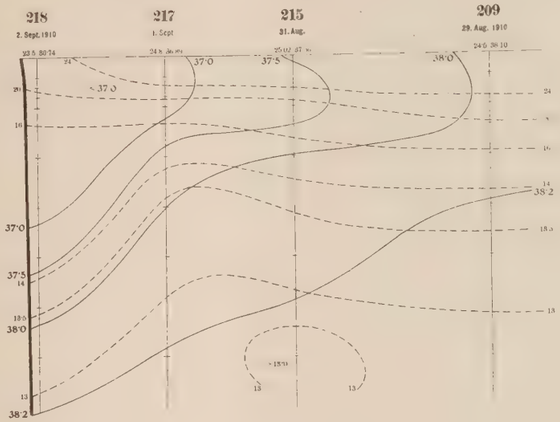

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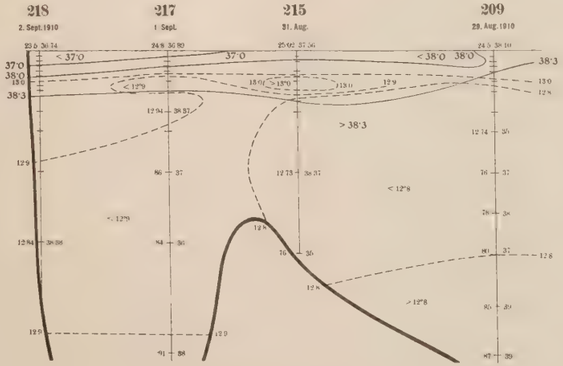

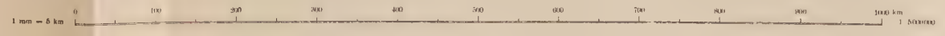

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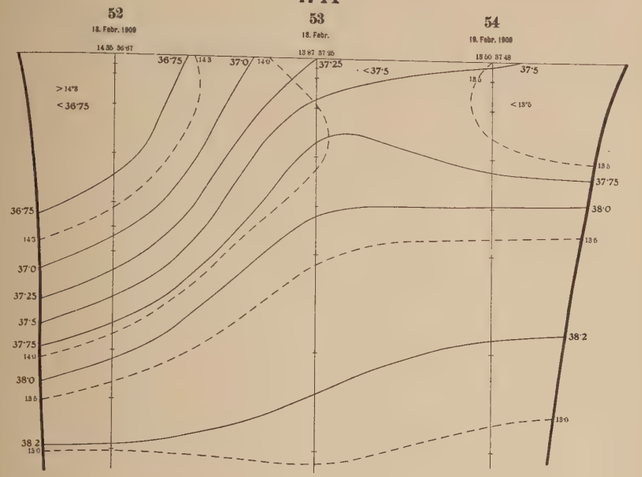

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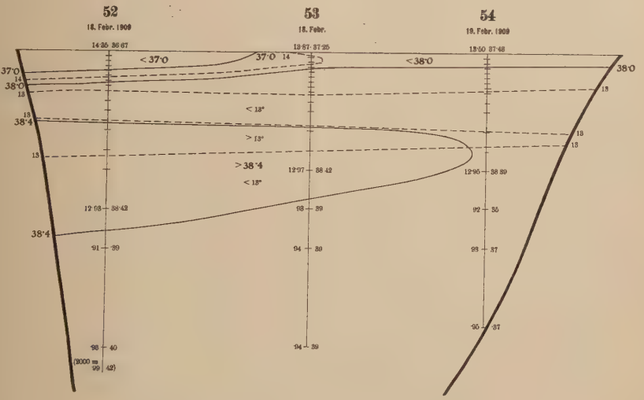

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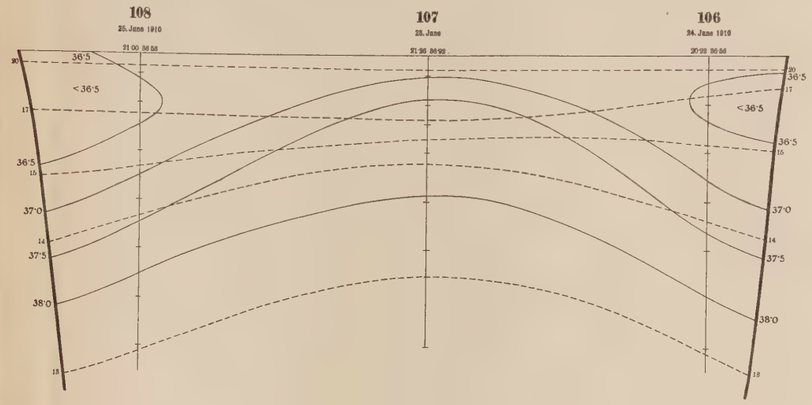

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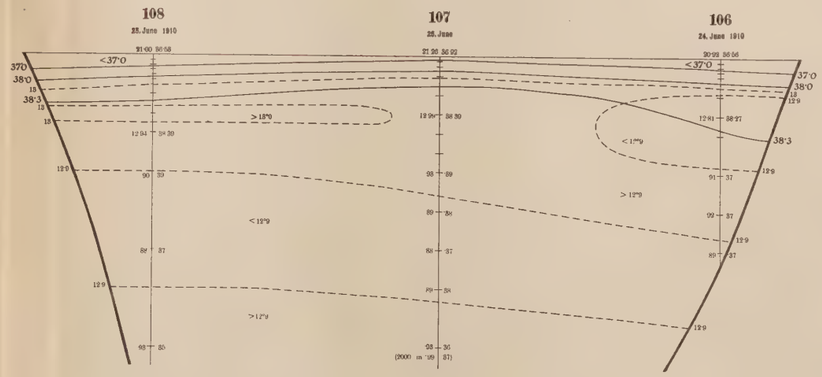

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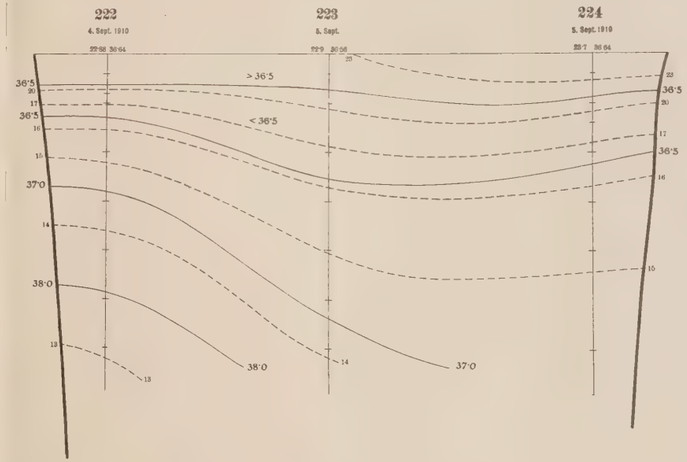

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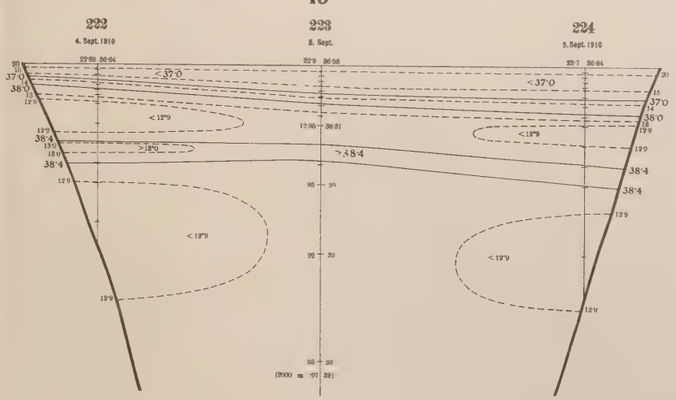
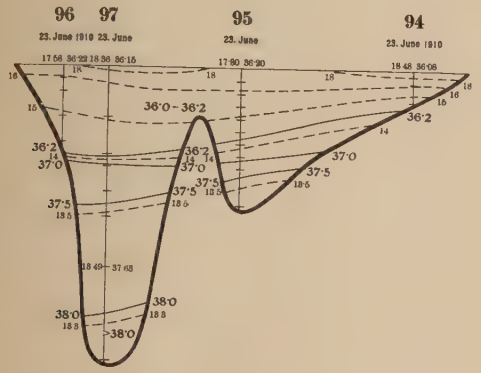


1 mm = 1 km 0 20 40 60 80 100 120 140 1 : 1000000
10 30 50 70 90 110 130 150 km

20



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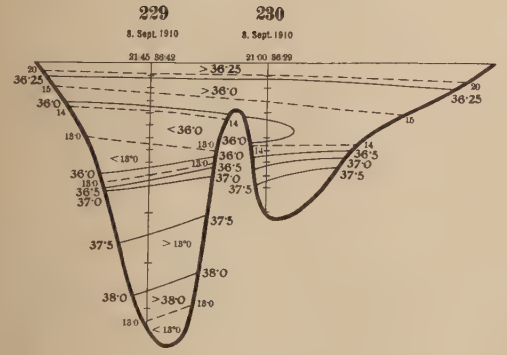

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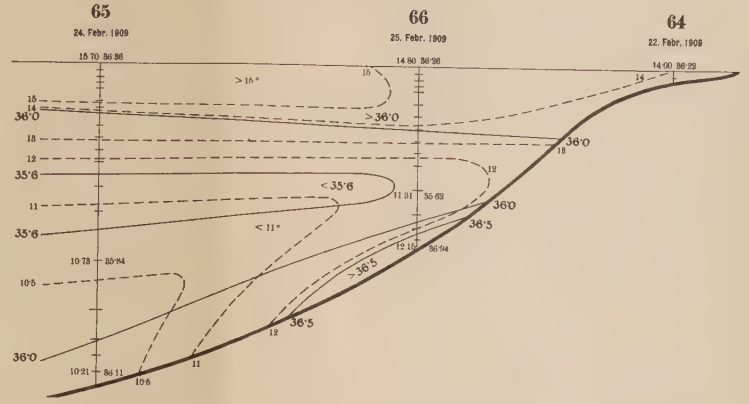

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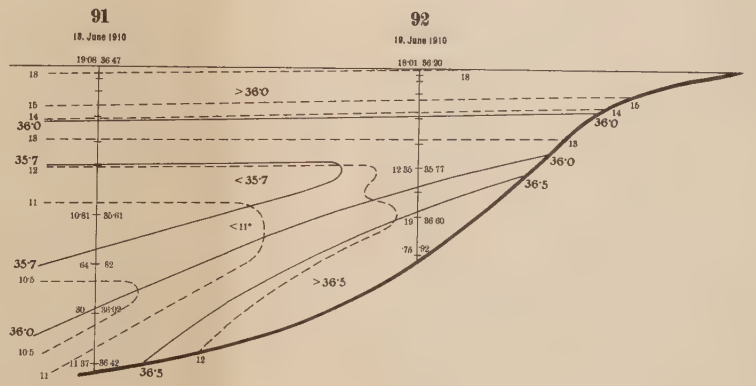
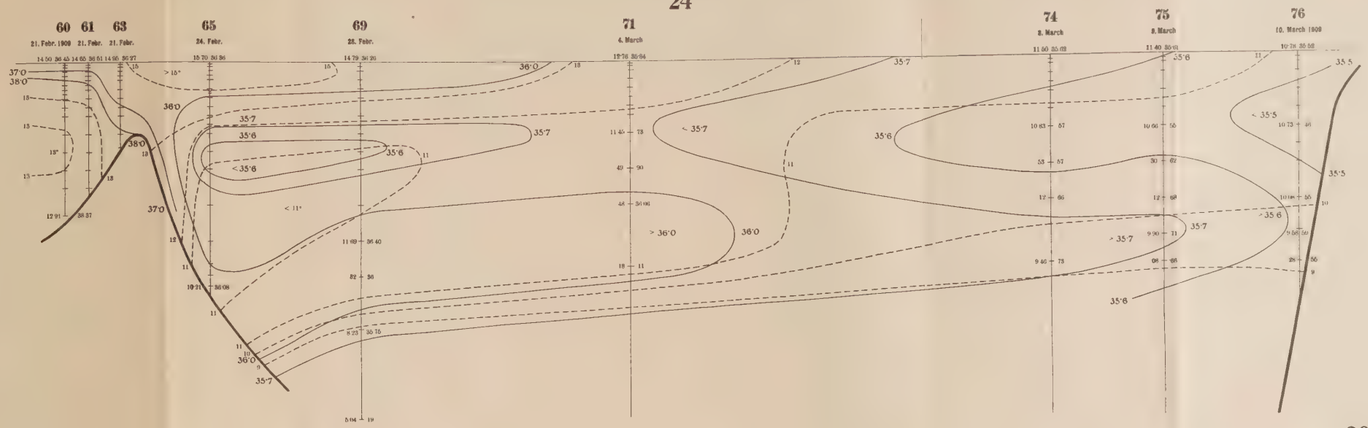
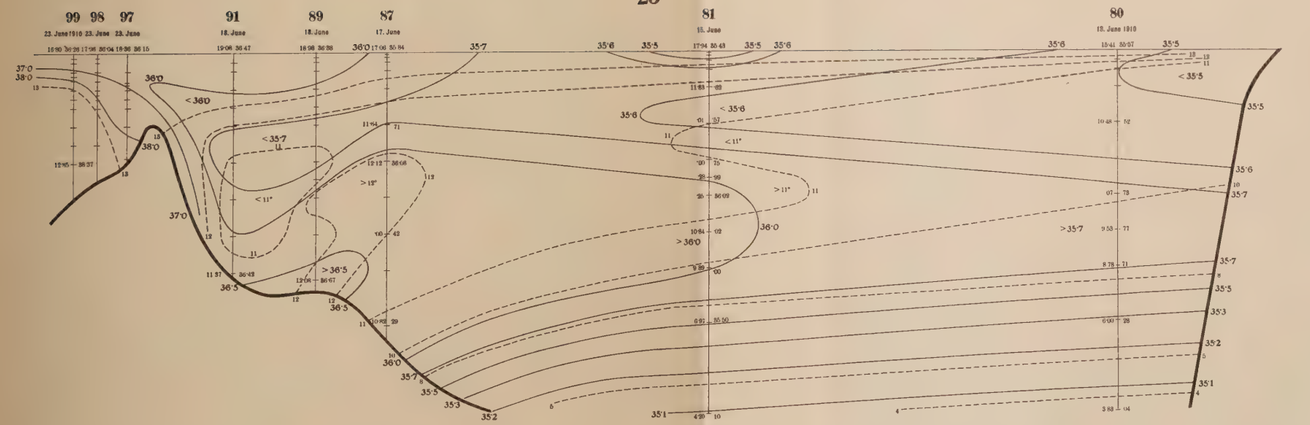


Carl Ahlers Etabls Repro Anstalt

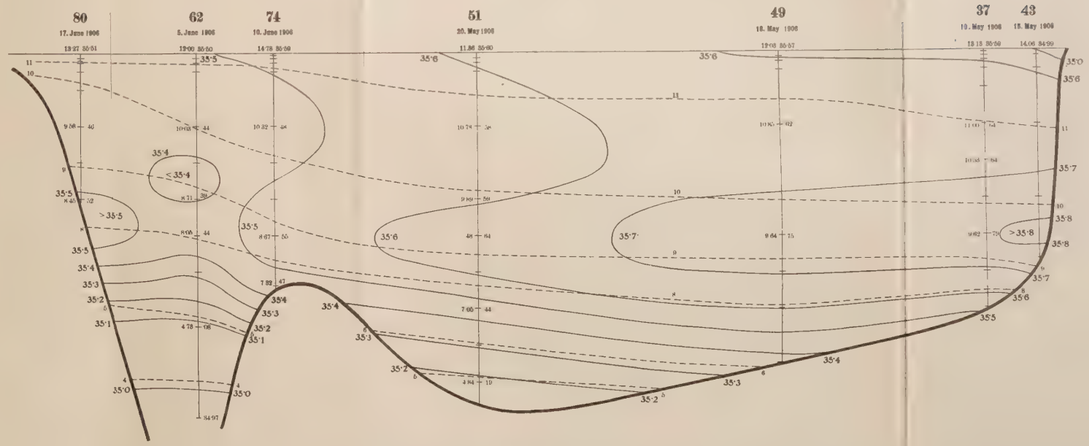
24


60 61 63
21. Febr. 1908 21. Febr. 21. Febr.
65
24. Febr.
69
28. Febr.
71
4. March
74
8. March
75
8. March
76
10. March 1908

25


99 98 97
23. June 1910 23. June 23. June
91
18. June
89
18. June
87
17. June
81
15. June
80
13. June 1910

26


80
17. June 1906
62
5. June 1906
74
10. June 1906
51
20. May 1906
49
18. May 1906
37
10. May 1908
43
15. May 1908

1 mm = 5 km
0
100
200
300
400
500
600
700
800
900
1000 km
1 : 5 000 000

Surface salinity
July 1910
Temperature and salinity
at 2000 m.
Temperature and salinity
at 300 m.
Temperature and salinity
at the bottom.
Temperature and salinity
at 1000 m.
Direction of movement
of the surface water.
of the intermediate water.

3.

Exact determination

of

the Chlorine in some samples of Seawater from the Mediterranean

by

H. Bjørn-Andersen

In February 1911 I was commissioned to determine the quantity of chlorine in 20 samples, taken in the deep water of the Mediterranean on the summer cruise of the "Thor" in 1910.

The investigation consisted in determining, how the amount of chlorine varied with the depth and as J. N. Nielsen[1] had already found, from the analyses made on board, that the variation amounted at most to some units in the 2nd place of decimals for the chlorine per mille, it was necessary to carry out the exact determinations within the limits of error $\frac{2}{10000} = \frac{1}{10000}$ in the unit.

A fully-prepared procedure lay already to hand in the method worked out in the year 1902[2] by S. P. L. Sørensen and myself for the determination of the chlorine in seawater. This has also been followed here, with some changes necessary in this case or to lighten the work.

Of each sample only about 200 cc. were available and as it was necessary to make two determinations in each case to avoid chance errors, I was only able to use ca. 75 cc. for each analysis, where 150 cc. had been used in 1902.

Further, the excess of silver nitrate has here been titrated volumetrically with 1/50 n. of the liquid instead of by weight with 1/20 n. of the liquid. Lastly, all the buoyancy corrections for the single weighings have here been omitted. The expression for ‰ *Cl* in seawater is $= 19.373 \times \frac{N.S_H}{H.S_N}$, where

N — the quantity of normal water weighed in the control analysis
S_N — - — silver nitrate — — —
H — - — of seawater weighed in the analysis
S_H — - — silver nitrate — — —

The corrections for buoyancy are always positive both in numerator and denominator and are approximately the same for normal water and seawater, as their density is almost the same. The corrections will thus neutralize each other.

The weighing of the solutions was undertaken in pipettes of 75 cc., the stalk being marked into divisions, so that the amount drawn off could be regulated within certain limits. Double weighings were always taken.

The procedure was thus in brief as follows. A portion of seawater (or normal water in controlling) was weighed off, diluted with 300 cc. water and slightly acidified with nitric acid. In a darkened room a slight excess of strong silver nitrate solution was then added. After repeated shaking and resting for 24 hours the liquid was decanted on to a filter carefully washed with dilute nitric acid, and the silver

[1] Regarding the hydrographical importance of the data found here, reference may be made to the paper published in this Report by J. N. Nielsen.

[2] Berichte über die Konstantenbestimmung zur Aufstellung der hydrographischen Tabellen: C. Forch, M. Knudsen and S. P. L Sorensen. Det kgl. danske Videnskabernes Selskabs Skrifter 1902.

chloride washed for a period of ca. 3 hours by means of 300 cc. of water slightly acidified with nitric acid, in 12 portions, The precipitate was shaken up well with the liquid and allowed to stand for 10 minutes before the liquid was decanted off on to the filter. After the final washing the precipitate with 50 cc. water added was allowed to stand till the next day, and the solution tested with a little ammonium sulphocyanate. It then gave as a rule no greater reaction than a solution of pure silver chloride. In a couple of cases where the opalescence was apparently a little greater, the washing was continued. The filtrate with the washing liquid was evaporated to dryness on the water-bath. The salt left was dissolved to 50 cc. and the excess of silver nitrate titrated back in the manner described in the work cited above.

Each analysis extended over 3 days. 1st day: weighing and precipitating. 2nd day: filtration, washing and drying. 3rd day: titrating.

The strong silver nitrate was tested 6 times with the normal water. These gave the mean 0.97501 (see Table III) for the relation between the weights of silver nitrate and normal water corresponding to one another. The average error of this mean is 0.00001.

The results of the analyses along with all the data necessary for the calculations are given in Table IV. In most cases the deviations from the mean are of the same order as found on testing with normal water.

In a few of the samples — especially No. 10 — the deviation is somewhat larger than was to be expected. The slightly greater error in this case has, however, no effect on the importance of the analysis in this connection.

I. Strength of the weak titration liquids in relation to one another.

10.00 cc. of ca. 1/50 n. $Ag\ NO_3$ corresponds to 10.32 cc. of ca. 1/50 n. $NH_4\ NCS$.

II. Strength of the weak titration liquids by comparison with normal water.

1 gr. normal water corresponds to 28.00 cc. of $NH_4\ NCS$.
(Mean of 7 determinations).

III. Strength of the strong solution of $Ag\ NO_3$ by comparison with normal water.

No.	Normal water gr.	Strong solution of $Ag\ NO_3$ gr.	1/50 n. $NH_4\ NCS$ cc.	1/50 n. $Ag\ NO_3$ cc.	gm. seawater corresponding to the weighed quantity of $Ag\ NO_3$	Relation $\frac{\text{gm. } Ag\ NO_3}{\text{gm. normal water}}$	dif. from mean
1	77,1846	75,9055	18,99	0,34	77,8503	0,97502	0,00001
2	77,1900	76,0903	24,97	1,02	78,0443	0,97498	0,00003
3	77,1682	75,6840	13,56	0,81	77,6225	0,97504	0,00003
4	77,1593	75,9932	22,70	0,79	77,9411	0,97502	0,00001
5	77,1615	75,9072	20,31	0,91	77,8533	0,97500	0,00001
6	77,1865	75,8365	17,54	0,80	77,7833	0,97498	0,00003
Mean						0,97501	

IV. Determination of the chlorine in the samples of seawater.

Stat. No.	No. of samples	Depth in meters	gm. of seawater	Strong solution of $Ag\,NO_3$ gm.	1/50 n. $(NH_4)NCS$ cc.	1/50 n. $Ag\,NO_3$ cc.	Strong solution of $Ag\,NO_3$ (corresponding to the weighed amount of seawater, gm.	$^0/_{00}$ Cl = gm. $Ag\,NO_3$ × 1.9373 / gm. seawater 0.97501	$^0/_{00}$ Cl, mean	Deviation of the single values from the mean
186	1	600	77,3335	83,6290	7,33	1,08	83,4124	21,4315	$21,432_5$	0,0000
"	"	"	75,8745	82,5950	22,84	1,05	81,8380	21,4315		
"	2	800	75,6911	82,1772	18,86	1,71	81,5818	21,4108	$21,411_8$	"
"	3	1000	74,9876	80,7011	9,80	12,02	80,7916	21,4077	$21,410_6$	0,0019
"	"	"	75,2595	81,5900	16,07	1,91	81,0980	21,4114		
"	4	1250	75,2257	81,5896	17,75	1,57	81,0279	21,4026	$21,401_1$	0,0015
"	"	"	75,4746	81,7156	14,30	1,87	81,2849	21,3996		
"	5	1500	75,5972	81,7113	9,39	0,81	81,4136	21,3988	$21,399_7$	0,0001
"	"	"	75,3321	81,6199	14,79	0,66	81,1286	21,3986		
195	6	800	75,9215	81,7436	6,66	0,90	81,5441	21,3413	$21,341_5$	0,0008
"	"	"	75,9156	81,6674	4,94	1,00	81,5312	21,3397		
"	7	1000	75,8978	81,6881	7,90	0,58	81,4339	21,3189	$21,319_2$	0,0003
"	"	"	75,8449	81,7312	11,81	1,65	81,3792	21,3194		
"	8	1250	76,3099	81,8494	2,63	0,83	81,7878	21,2961	$21,297_5$	0,0004
"	"	"	75,9090	81,6933	10,41	0,86	81,3618	21,2968		
"	9	1500	76,1749	81,7337	5,38	1,83	81,6122	21,2879	$21,289_5$	0,0006
"	"	"	75,8638	81,7079	13,00	0,79	81,2834	21,2890		
"	10	2000	76,0944	81,7800	10,58	0,91	81,4443	21,2667	$21,268_7$	0,0010
"	"	"	75,8234	81,7680	18,79	1,34	81,1618	21,2686		
206	11	600	76,0205	81,7699	13,64	1,39	81,3447	21,2614	$21,262_9$	0,0005
"	"	"	75,9855	81,6557	10,57	0,66	81,3113	21,2624		
"	12	800	75,8580	81,6100	14,61	0,70	81,1263	21,2497	$21,250_7$	0,0001
"	"	"	75,8865	81,5997	13,19	0,46	81,1568	21,2496		
"	13	1000	75,8371	81,6475	16,40	0,63	81,0991	21,2483	$21,248_9$	0,0005
"	"	"	75,9229	81,6153	13,04	0,75	81,1880	21,2474		
"	14	1250	75,8414	81,6393	15,79	0,45	81,1055	21,2486	$21,250_8$	0,0012
"	"	"	76,0581	81,6902	10,60	0,70	81,3462	21,2510		
"	15	1500	76,9768	82,6122	8,81	1,61	82,3632	21,2603	$21,260_9$	0,0004
"	"	"	75,9850	81,6599	11,10	0,79	81,3016	21,2595		
"	16	2000	75,8419	81,5642	13,40	0,64	81,1202	21,2526	$21,254_5$	0,0009
"	"	"	75,7573	81,6507	18,09	0,42	81,0358	21,2543		
"	17	2500	75,8736	81,7231	17,28	0,53	81,1405	21,2491	$21,250_8$	0,0007
"	"	"	76,0034	81,6756	11,81	0,56	81,2846	21,2505		
160	18	2000	75,3279	81,6793	18,38	2,25	81,1201	21,3978	$21,399_4$	0,0016
"	"	"	75,2633	81,7387	20,49	1,01	81,0614	21,4009		
"	19	2500	75,2677	81,7643	21,90	1,35	81,0501	21,3968	$21,400_8$	0,0030
"	"	"	75,3924	81,7763	17,54	1,19	81,2084	21,4028		
"	20	3000	75,6525	81,7826	10,09	1,43	81,4828	21,4010	$21,403_6$	0,0016
"	"	"	74,8465	81,7025	31,81	0,86	80,6258	21,4041		

Chemical Laboratory
Polytechnic College.
Copenhagen, 21/9 1911.

4.

Determination of the quantity of Oxygen in Seawater

(Methods used)

by

Sven Palitzsch

During the Expeditions the oxygen contents of a little over 1000 samples of seawater were determined.[1] The method used was that given by L. W. Winkler [1888 p. 2843 and 1889 p. 1764]. Winkler adds manganous chloride and sodium hydrate to the sample containing oxygen; manganous hydrate is thus formed, which takes up the oxygen with the formation of manganic hydrate. On making the liquid acid with hydrochloric acid and adding potassium iodide, an amount of iodine is separated out equivalent to the amount of magnesium and thus to the original quantity of oxygen. The amount of iodine can then be determined by titration with a thiosulphate solution.

The following equations represent the processes:

$$2\ MnCl_2 + 4\ NaOH = 2\ Mn(OH)_2 + 4\ NaCl$$
$$2\ Mn(OH)_2 + O + H_2O = 2\ Mn(OH)_3$$
$$2\ Mn(OH)_3 + 6\ HCl = 2\ MnCl_3 + 6\ H_2O$$
$$2\ MnCl_3 + 2\ KI = 2\ MnCl_2 + 2\ KCl + I_2.$$

For the collection of the water-samples the ordinary bottles and apparatus used by the Hydrographical Laboratory in Copenhagen (Kommissionen for Havundersøgelser) were employed. The bottles contain about 150 cc. and are provided with a carefully ground glass-stopper.[2] When filling, which is done directly from the water-bottle, a double-bored rubber cork is placed in the neck of the bottle and through this is inserted on the one side a long glass tube, which is connected by a piece of rubber tubing to the outlet of the water bottle; on the other side is a short tube which only reaches just below the stopper. With this arrangement the bottle is filled from below and the water which runs in first and which has been in contact with the air in the bottle, is allowed to flow out through the short tube. About 150 cc. are run out and it is thus fairly certain that the water in the bottle has not been in contact with the air. The quantity of the water run out is most easily determined by letting it fill another bottle of 150 cc. capacity.

After filling and rinsing, the rubber stopper is removed and the reagents added by means of pipettes with long and thin stalk, which can reach to the bottom; first a 1 cc. solution of sodium hydrate containing potassium iodide and then a $^1/_2$ cc. solution of manganous chloride. A copious white precipitate is at once formed which absorbs the oxygen and care has to be taken therefore, when the pipettes are withdrawn, that no precipitate is formed on the surface of the water. If there is much carbon dioxide in the water, which is to be investigated, more manganous chloride has to be added, as manganous carbonate is inactive. J. P. Jacobsen [1905 p. 7] has shown, that even 4 times the intended quantity of the reagents does not affect the result. It is best to take a new pipette for each test; if the pipette is thoroughly dried each time, however, one pipette for each reagent may suffice. The pipettes are easily cleaned with strong hydrochloric, which is washed off with distilled water. The glass stopper is now carefully placed in the bottle, so as to leave the latter completely full without a single air-bubble remaining. Stoppers with a cavity below or with air bubbles in contact with their under surface must be rejected. A spring-

[1] Only the analyses of the summer cruise have been made by the author, the samples from the winter cruises were taken to Copenhagen and analysed at the Hydrographical Laboratory.

[2] The exact determination of the cubic contents will be mentioned later.

catch of brass-wire is fitted round the neck of the bottle and over the stopper so that the latter is pressed down tight to the bottle. The bottle is inverted quickly a couple of times, to distribute the precipitate evenly through the whole quantily of water and then placed in a solid glass bottle, which is filled with sea-water and closed with a cork. When the water in the inner bottle contracts owing to change of temperature, water and not air will be sucked in. Both the bottles and the stoppers, especially the cork stoppers, must be numbered distinctly.

The bottles can readily and conveniently be placed in cases divided into compartments by wooden partitions and packed with wood-flock or the like; each bottle has then its separate compartment and can remain there any length of time without rolling. It is best to place a piece of cork in the bottom of the outer bottle, otherwise the inner bottle may knock the latter out if the case is dropped a little too hard on the deck. The cases should not be larger than to contain 25 bottles, or they become too unwieldy.

When the water-samples to be analysed for oxygen have been treated in this way, they can stand for several weeks, as BJERRUM [1904] has shown, and yet give the same result on titration as a sample tested at once. When the precipitate in the bottle has settled, or some time later, ca. 2 cc. 33% hydrochloric is added, and the stopper fixed on so that no air bubble is left behind. The 2 cc. of water thus removed have no influence on the analysis, as the manganous hydrate of the precipitate has absorbed all their oxygen. When the hydrochloric has dissolved the precipitate the clear solution coloured yellow with free iodine will no longer be able to absorb oxygen; it can be poured over into a conical glass vessel of 350 cc. and titrated with thiosulphate. With the iodine the thiosulphate forms sodium iodide and sodium tetrathionate, according to the equation:

$$2\ Na_2\ SO_3 + I_2 = 2\ Na\ I + Na_2\ S_4\ O_6.$$

The titration is continued until the yellow colour has almost disappeared, then the bottle is washed by pouring some of the decoloured liquid from the beaker into it and back again; the liquid still adhering to the bottle contains so little iodine that it is of no importance for the result. Lastly, addition is made of ca. 2 cc. 1% starch solution and thiosulphate until the blue colour disappears.[1] The beaker can be washed out with seawater.

The reagents used for the analysis were prepared in the following way.

The manganous chloride solution was prepared by dissolving 200 gm. $Mn\ Cl_2, 4\ H_2\ O$ in 500 cc. water, 2cc. strong hydrochloric acid being added to prevent the formation of turbidity or precipitate which might absorb oxygen.

The sodium hydrate solution was prepared by dissolving 180 gm. sodium e natrio in ca. 350 cc. water; after cooling the solution was poured into a measuring-glass of 1/2 a litre containing 10 gm. potassium iodide, and the solution was diluted to bring it up to 1/2 a litre.

The hydrochloric acid was ca. 33% strong and was prepared by mixing 3 volumes of concentrated hydrochloric acid with one volume of water.

For the starch solution 2 gm. soluble starch were taken, heated up with 200 cc. water to boiling,

[1] As soon as the liquid is made acid by the addition of hydrochloric acid, the whole of the iodine corresponding to the manganic hydrate is at once set free. (In three determinations of the oxygen in the same samples of seawater, 5.54 cc. oxygen was found on titration immediately after the addition of the acid, and 5.56 and 5.55 cc. of oxygen when the titration was made 24 hours after the addition). The blue colour which appears on standing in the liquid decoloured by thiosulphate cannot therefore be due to the chemical processes expressed in the equations on p. 201 not coming to an end at once; on the contrary it is caused by the hydrogen iodide becoming oxidized by the oxygen taken up by the liquid during titration and for this reason it is not advisable to stir up the liquid with a spatula. A sufficiently complete mixture is produced by rotating the liquid in the beaker in which the titration is made. In this case the oxidation will be so slight and produced so slowly, that it does not attain to any appreciable dimensions in the time required for the titration. That the blue after-colour is due to atmospheric oxygen has been shown by using solutions free of oxygen and saturated with carbonic acid and titrating in an atmosphere of carbonic acid The blue colour did not appear.

filtered through Chardin's filter paper and cooled. The solution does not keep well. It was only used so long as it gave a sharp colour-change from blue to colourless without red transitional stages.

The thiosulphate solution used was about n/100; 2 to 2.5 gm. $Na_2SO_3, 5H_2O$ in the litre, On bord its strength was determined by a solution of potassium bi-iodate (see below).

The seawater and reagents must not contain compounds which will separate out the iodine. The nitrous acid in seawater will give too high values for the oxygen, as a rule however the quantity of nitrous acid is so infinitesimal that it is of no importance [Raben; 1904 p. 89]. The reagents must be tested separately; they should not separate out the smallest quantity of free iodine from an acid solution of potassium iodide, that is to say, the potassium iodide must contain no iodate, the manganous chloride no iron, the sodium hydrate no sulphurous acid and the hydrochloric no free chlorine. The test was made by taking 5 times the quantity of the reagents as for our analyses, diluting with water to 150 cc. and adding starch; no blue colour appeared.

Strength and standardizing of the thiosulphate.

As it is usually only a matter of small differences in the oxygen contents of the seawater and the iodine method permits of an extremely sharp titration, it is better to use a fairly weak thiosulphate solution; usually an n/100 solution is used. To avoid the inconvenience in the iodine method of the thiosulphate not keeping, Ruppin [1909 p. 284] recommended the preparation of an n/5 solution, diluting this with boiled distilled water so as to have just enough for use for one day. Ruppin states that an n/10 solution changed only 1% in the course of a whole year.

If we use boiled water however and cover the bottle in which the thiosulphate is kept with an opaque layer of asphalt-lac and allow the solution to stand ca. 14 days or more before use, even an n/100 solution will keep sufficiently unchanged. On the Thor Expedition a solution of this kind changed less than 3‰ in the course of the ten days during which it was used[1]. Preparation of a stronger solution and its dilution may perhaps therefore be said to be an unnecessary inconvenience. Even if fresh boiled water cannot be obtained on board, it is yet more convenient to determine the sulphate each day. The reduction in strength during one day will in any case not be noticeable, if the solution has only stood sufficiently long in a full bottle before using.

The strength of the thiosulphate was determined by means of a solution of potassium bi-iodate of known strength [cf. R. Koefoed, 1910 p. 428]. With a Knudsen pipette 15 cc. of the latter were measured into 200 cc, water, 10 cc. 5% potassium iodide and 2cc. strong hydrochloric being added. The separated iodine was titrated in the ordinary way with the thiosulphate solution. The potassium bi-iodate solutions used contained respectively 0.8552 and 0.8587 gm. pure bi-iodate per litre[2]; they were kept in glass bottles with ground glass-stoppers, over which could be placed a small glass bell, which closed tight on a rubber ring round the neck of the bottle. In this way an air-free space was obtained, without the bi-iodate being able to come in contact with the rubber. The strength of the solution remains unchanged for a long time. A year after the preparation of the solutions used on the Expedition, their strength was compared with a freshly prepared bi-iodate solution as also with the solution used by J. P. Jacobsen on titrating the samples of seawater collected partly on the winter cruise, partly by the hydrographers of the Prince of Monaco (cf. J. P. Jacobsen's paper). All the solutions were titrated in the ordinary way with the same thiosulphate solution, and from the data found for the freshly prepared solution was calculated the number of cc. thiosulphate which would be required for the titration of the other solutions, provided that the strength of these had remained unchanged.

[1] The burette must not be filled by pouring in the liquid, this should be run in from below.

[2] The solution was prepared at 17.5° C. in a retort, which was assayed in Charlottenburg, Berlin.

	gm. bi-iodate	cc. thiosulphate found	cc. thiosulphate calculated
New solution.	0.8160 in 1000 cc. sol.	34.75—34.75—3475	
	0.8183 - 1000 gm. -		
"Thor 1"	0.8552 - 1000 cc. -	36.65—36.65	36.42
— 2"	0.8552 - 1000 - -	36.40—36.45—36.45	
— 3"	0.8587 - 1000 - -	36.65—36.68	36.57
— 4"	0.8587 - 1000 - -	36.63—36.60	
"Jacobsen"	0.5964 - 1000 gm. -	25.22—25.18—25.18	25.33

As will be seen the agreement is very good, only the "Thor 1" showing a difference of a little over $^1/_2$ %, and the reason for this is certainly, that almost the whole of the contents were used and the remainder through evaporation of a little water became slightly more concentrated, "2" was quite untouched, "3" and "4" were scarcely half full.

As the potassium bi-iodate occurs in the trade in very different qualities [Bjerrum 1904 p. 6], it is necessary once and for all to test the purity of the preparation. The degree of purity is determined[1] by standardizing the same thiosulphate solution both with bi-iodate and with sodium oxalate.

The sodium oxalate was used as indicated by S. P. L. Sørensen [1903 p. 429]. A weighed quantity of the salt, dried in a vacuum over sulphuric acid, was decomposed and heated over a spirit flame, dissolved in a definite quantity of acid, boiled to drive off the carbonic acid, then potassium iodide and potassium iodate were added and the amount of iodine separated out was titrated with thiosulphate solution; exactly the same quantity of acid was also titrated without the sodium oxalate. As respectively a and b cc. thiosulphate were used for this purpose and the oxalate weighed c gm. ($^1/_2\ Na_2\ C_2\ O_4 = 67$), the thiosulphate was $\frac{c \times 1000}{67\,(b-a)}$ normal (regarding details, see R. Koefoed l. c.).

(1000 cc. normal thiosulphate correspond to 67 gm. sodium oxalate, thus 0.0335 gm. to 50 cc. n/100 solution; if five times as much is weighed off and dissolved after glowing in 100 cm. ca. n/20 hydrochloric acid, diluted after boiling off the carbonic acid to 250 cc. and 25 cc. titrated, these 25 cc. will correspond to 1/10th of the weighed quantity and thus on titration use ca. 50—25 = ca. 25 cc. n/100 thiosulphate).

The same thiosulphate was then standardized by means of bi-iodate. As a molecule of bi-iodate weighs 389.95 gm., which in accordance with the equation: $KIO_3,\ HIO_3 + 10\ IK + 11\ HCL = 11\ KCL + 6\ H_2O + 6\ I_2$, sets free 12 atoms of iodine, 390/12 = 32.5 gm. bi-iodate will be equivalent to 67 gm. sodium oxalate. A suitable quantity (ca. 0.85 gm.) of bi-iodate was weighed off, dissolved in water to 1000 cc.; 15 cc. of this, corresponding to p gm. bi-iodate, were diluted with 200 cc. water and titrated, after addition of potassium iodide and hydrochloric (see above) with e cc. of thiosulphate, which standardized with sodium oxalate was found to be $\frac{c + 1000}{67\,(a-b)}$ normal, thus to contain one equivalent in $\frac{67\,(a-b)}{c}$ cc., which therefore will correspond to 32.5 gm. bi-iodate (= one equivalent of perfectly pure salt); consequently, p gm. will correspond to $\frac{p}{32.5} \times \frac{67\,(a-b)}{c} = q$ cc. thiosulphate. As the quantity of thiosulphate used in titrating was e cc. the degree of purity of the bi-iodate will be $\frac{e}{q}$. 100 %. The preparation used on the Thor Expedition was made up by "C. A. F. Kahlbaum" and proved to be perfectly pure when analysed in this way; the degree of purity was 100 %.

Calculations of the analysis.

According to the equations p. 201, 1 atom of oxygen corresponds to 2 atoms of iodine or 8 gm. oxygen to 126.9 gm. iodine. 1 cc. n/100 thiosulphate, which is equivalent to 0.001269 gm. iodine, thus

[1] The determination was made by R. Koefoed: l c. pp. 428 and 429.

corresponds to 0.00008 oxygen. If the strength of the thiosulphate is $p \times \frac{n}{100}$ (see p. 204), 1 cc. will correspond to $p \times 0.00008$ gm. oxygen. In hydrographical work, however, for the sake of comparison with the earlier volumetric investigations, the oxygen is not given by weight but by volume in cc. at 0° and 760 mm. pressure. As one litre of oxygen at 0° and 760 mm. weighs 1.43 gm., each cc. n/100 thiosulphate corresponds to 0.0559 cc. oxygen.

If m cc. $p \frac{n}{100}$ thiosulphate are used for analyses and the capacity of the bottle is R, the quantity of oxygen in 1000 cc. seawater is $55.9 \times \frac{p \times m}{R}$ cc. oxygen.

In the calculations of the analysis, however, it is not necessary to first work out the normal factor for the thiosulphate (p); we can make the whole calculation at one time by using as basis the amount of pure salt in the potassium bi-iodate solution used for the standardization of the thiosulphate solution.

On the Thor Expedition, for example, the analyses were worked out in the following way.

A molecule of potassium bi-iodate (KIO_3, HIO_3) corresponds in the analysis, according to the equations given above, to 12 atoms oxygen. 1 gm.-molecule KIO_3, HIO_3 weighs 390 gm., 1 gm.-atom oxygen 16 gm. and 1 cc. oxygen 0.00143 gm.; consequently 1 gm. bi-iodate corresponds to $\frac{6 \times 16}{390 \times 0.00143} =$ 172.3 cc. oxygen.

If, now, s cc. thiosulphate are used in the titration of r cc. bi-iodate solution in the pipette[1], the latter solution containing $\frac{k \times r}{1000}$ gm. salt, where k is the number of gm. bi-iodate in one litre, and w cc. are used in the titration of the contents of a "Winkler bottle", which holds f cc.[2], the number of cc. oxygen at 0° and 760 mm. in 1000 cc. seawater will be

$$k \cdot r \cdot 172.3 \frac{1}{s} \cdot \frac{w}{f}.$$

In addition to the number of cc. oxygen in 1000 cc. seawater, calculation has also been made of the percentage quantity of oxygen present in comparison with the quantity occurring in seawater at the same temperature and salinity when this is saturated with oxygen, that is, in equilibrium with air containing 20.8 % oxygen at 760 mm. pressure. On the basis of 48 experiments J. P. Jacobsen [l. c. p. 10] has made up the formula;

$$M = 10.062 - 0.2822\,t - 0.006144\,t^2 - 0.000061\,t^3 - 0.1073\,Cl + 0.003586\,t\,Cl - 0.0000550\,t^2\,Cl$$

M is the quantity of oxygen in the water saturated with oxygen, t is temperature and Cl the quantity of chlorine in ‰. By means of this equation a table has been calculated for oxygen-saturated seawater at temperatures from 0° to 25° and with quantities of chlorine from 0 to 20 ‰. For the Mediterranean water, which for the most part has more than 20 ‰ Cl, more values had to be calculated, and this could be done with sufficient exactness by extrapolation from the numbers of the table[3].

Titration of the oxygen by Winkler's method is much easier and better suited to work on board than any of the volumetric and toniometric methods; these require a comparatively long time and complicated glass apparatus, which very readily lead to confusion on board a ship; the rubber tubes rapidly become leaky, even protected mercury or air columns move up and down in the measuring tube with the rolling of the ship and the oscillations never fall regularly about the centre of equilibrium. Winkler's method, on the other hand, is extremely suited for use on board ship; in bad weather as many water

[1] The capacity of a "Knudsen pipette" of 15 cc. was found by weighing the quantity of water, which ran out of the pipette when filled at 17.50 °.

[2] The capacity of the bottle was determined by weighing it empty and filled with distilled water; the weighing was carried to 0.1 gm. exactness. In reality 1.5 cc. should be subtracted as the volume of water is reduced by the addition of the reagents; according to Bjerrum (1. c. p. 6), this is not necessary, as the reagents also contain oxygen. In calculating the oxygen analyses of the Thor Expedition, the capacity of the bottle was used without reduction.

[3] The differences in J. P. Jacobsen's table between the found and calculated values range from + 0.05 to — 0.07 (with 5 exceptions.)

samples for analysis of the oxygen can be collected as is desired, and the titrations need only be made when the sea and time permit. The experience of the German Valdivia Expedition [Brennecke 1909 p. 17], where ca. 200 Winkler analyses were made on board, was quite the same. The titration itself only takes 3 to 4 minutes, so that ca. 100 analyses can be made with ease in one day. The change from blue to colourless can be seen excellently by electric light (tantallum lamps [Ruppin, 1909 p. 284]). The only inconvenience in the method is the measurement of the reagents with the thin pipettes. This has to be done immediately after the water-sample has been drawn from the water-bottles and is a very awkward and disagreeable work, especially in bad weather and high sea.

Determination of the quantity of hydrogen sulphide.

On the Expedition some few stations were investigated in the Black Sea. Here the quantity of oxygen decreased very rapidly with the depth and was found to be 0 already at ca. 180 meters, the water from greater depths contained hydrogen sulphide. The water was dealt with and titrated in quite the same way as for an ordinary oxygen analysis, but 8 cc. potassium bi-iodate solution of known strength were added to the hydrochloric liquid. The colour change was very indistinct as the sulphur separated out gave the liquid decolourized by the thiosulphate a bluish, opalescent tinge. From the difference between the quantity of thiosulphate necessary for the 8 cc. bi-iodate solution and that for the analysis, the quantity of hydrogen sulphide in the seawater was calculated, on the supposition that the whole of the hydrogen sulphide acted to reduce the iodine separated from the bi-iodate and the potassium iodine. The number of cc. hydrogen sulphide is calculated in the same way as the oxygen, except that the number found has to be multiplied by 2, as the gm.-molecule KIO_3, HIO_3 corresponds to 3 gm.-molecules ($=3\ O_2$) of oxygen but to 6 gm.-molecules ($=6\ H_2\ S$) of hydrogen sulphide.

As strong hydrochloric was added before titration, the numbers found give the total quantity of the hydrogen sulphide which occurs free and that which occurs bound as soluble sulphides.

Arsenius Lebedinzeff, [1893 p. 2] who has made the most quantitative determinations of hydrogen sulphide in seawater, used a solution of a weighed quantity of iodine in potassium iodine and titrated the iodine, not reduced by the hydrogen sulphide, with sodium thiosulphate.

Carlsberg Laboratory, March 1911.

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5.

The amount of Oxygen in the water of the Mediterranean

by

J. P. Jacobsen

CONTENTS.

page

Introduction 209
Variation in the amount of oxygen in the 24 hours, for the surface and adjacent layers 210
Variation in the amount of oxygen with the season of the year 216
Variation in the amount of oxygen with the locality 222
a. Atlantic 222
b. Balearic Sea 225
c. Tyrrhenian Sea 229
d. Ionian Sea and Sidra Sea 230
e. The Levant 232
f. Aegean Sea 233
g. Sea of Marmora 234
h. Black Sea 235
Summary 235
Bibliography 236

I. INTRODUCTION.

Investigations on the amount of oxygen in the water of the Mediterranean, like the scientific marine investigations in general, are of comparatively recent date. The most complete investigations of earlier years are those of Natterer (1892, pages 83, 105) from the Pola Expedition. We shall discuss these later, but it may be mentioned, that they were only concerned with the Eastern Mediterranean.

At a still earlier date (1870) Carpenter and Jeffreys had carried out some determinations of the oxygen in the Mediterranean on the Porcupine Expedition and in 1871 Carpenter also studied the same question on the voyage with the surveying ship "Shearwater". In the first report on these investigations (1871, p. 203) it is stated, "There is another condition however, which may be not less potent in restraining within very narrow limits the animal life of the deeper parts of the Mediterranean Basin — namely the stagnation produced by the almost entire absence of vertical circulation.... It is difficult in fact to conceive of any agency, that can disturb the stillness of the abyssal depths of a basin which is completely shut in by a wall, that rises more than 10,000 feet from its bottom. How far this affects the condition of such depths in respect to the diffusion of the organic matter and the oxygen required for the support of animal life, must be a matter of future inquiry". In the second report (1872, p. 586) we also find: "Thus it appeared that very nearly the whole available oxygen had been converted into carbonic acid".

This important question, which is put forward in the above, has not however received the correct answer; the few analyses which formed the basis of the conclusions must be considered to have been carried out in a wrong way.

Within recent years investigations on the amount of oxygen have again been taken up and from various sides. From the Straits of Gibraltar and a single station (44) in the Alboran Sea we have some observations reported on by H. N. Dickson (1909). Comparison with the results obtained from the investigations of the "Thor" leads us to suspect, however, that some of these determinations were inexact.

Lastly, I may mention Brennecke's determinations (1909, p. 51) of the amount of oxygen at a station close outside Gibraltar, and also the observations made from the Italian and Austrian sides in the Adriatic (Brückner 1911, p. 193 and Grund 1911, p. 262).

The determinations of the amount of oxygen in the Mediterranean and adjacent waters, which were made on the cruises of the "Thor" in the winter of 1909 and summer of 1910, number about 1200. The stations at which the amount of oxygen was determined on the winter cruise lie for the most part in the Balearic and Tyrrhenian Seas and were not numerous (85 samples), the samples for the determination of the oxygen according to Winkler's method being kept on board and only analysed after the return home. On the summer cruise samples were taken regularly for the determination of the oxygen at the same stations where temperature and salinity observations were made. The analyses were carried out on board according to Winkler's method. As will be seen from the tables, the regular variation of the amount of oxygen with the depth shows, that considerable accuracy in the determination can be attained to, both by keeping the samples as well as by making the analyses on board. The analyses from the summer cruise were made by Sven Palitzsch, who has already described in detail the methods used.

Consideration of the different sections and their position, Pl. XII—XVII will soon give a comprehensive view over the amount of oxygen at the different places in the Mediterranean and it is not difficult to detect a certain regularity in the variations with the place and depth. It is seen, for example, that the relative amount of oxygen in the surface-water is at most places ca. 100 % or a little less, whilst in the deepest layers it lies as a rule between 70—80 %, according to the locality.

In the Sea of Marmora and the Black Sea the conditions are different; here the relative amount of oxygen sinks to much smaller values, in the Black Sea even to 0, so that the continued reduction leads to the development of hydrogen sulphide. This has been demonstrated earlier by Lebedintsef (1893, p. 420).

In the Mediterranean, on the other hand, the conditions are more uniform and we find as a rule a minimum in the amount of oxygen between the surface and the deep layers. Lastly, supersaturation is frequently found, at least at certain times, in the uppermost layers at a depth of ca. 50 m.

We shall return later to a more detailed description of the amount of oxygen at the different places, but meanwhile we may endeavour from the available material to ascertain as far as possible the fluctuations in the amount of oxygen with the time.

The relative amount of oxygen depends in part on the absolute amount, in part on the temperature and salinity; all three dimensions may vary from purely physical causes. For example, if the seawater at the surface is undersaturated at a given moment, oxygen will be absorbed from the atmosphere and the amount of oxygen rise. If the temperature is changed, the amount of oxygen necessary for saturation of the water will be different and the relative amount of oxygen thus altered. The salinity of a layer changes usually very little (from evaporation, diffusion); on the other hand, currents and mixing of the different layers may lead to all the physical dimensions altering at a given locality.

Lastly, the absolute amount of oxygen and therewith also the relative may be changed by the agency of organisms in the seawater or by the decomposition of dead organisms. The production of oxygen by the plankton depends, as known, on the light, thus again on a physical cause.

If we wish, therefore, to study the variation in the amount of oxygen with the time, we must refer it to the same periods that are found in the physical factors mentioned, which means reference to day and night and the seasons. For more detailed investigations, e. g. of unperiodic changes in the physical factors, the material is scarcely sufficient.

II. Variation in the amount of oxygen in the 24 hours, for the surface and adjacent layers.

To investigate how far there is a daily period in the amount of oxygen at the surface, the stations which lie approximately in the same region and which were investigated at the same time of year, have been taken together in groups and within each of these groups they have been taken in 2 divisions, those investigated between 10 a. m. and 8 p. m. and those investigated between 8 p. m. and 10 a. m.; for each of these the average has then been calculated, both for the relative and the absolute values of the amount of oxygen in the surface-water.

As will be seen from Table 1 the differences between these averages are mainly positive and if we weight each of the differences by an amount proportional to the number of stations in the smallest division in a group, we find that the average difference for the relative amount of oxygen in the two parts of the 24 hours is 1.8 % and the average difference for the absolute amount of oxygen 0.08 cc. If we take the amount of oxygen in the surface-water to be ca. 5 cc., the latter difference is thus 1.6 % of the whole value. We see, therefore, that both the relative and the absolute amount of oxygen show

almost the same difference for the two parts of the day, from which it follows, that it cannot be the daily period in the surface-temperature which plays the determinating role, as we might imagine if the absolute amount of oxygen found in water had been the same for the two periods of the 24 hours and the difference was only found for the relative amount of oxygen owing to the daily period in temperature.

Table 1. Variation in the amount of oxygen in the surface-water during the 24 hours.

Region	Groups of stations: I. Observations between 10 a. m. and 8 p. m. / II. Observations between 8 p. m. and 10 a. m.	Relative amount of oxygen in °/₀: Average for relative amount of oxygen	d Differences between averages for I and II	v Weights of the differences	$d \times v$	Absolute amount of oxygen in cc.: Average for absolute amount of oxygen	d' Differences between averages for I and II	v' Weights of the differences	$d' \times v'$
Atlantic $^{13}/_{6}$—$^{19}/_{6}$	I. 80-81-84-87-91	107.6	8.0	2	16.0	5.90	0.56	2	1.12
	II. 89-92	99.6				5.34			
Straits of Gibraltar $^{23}/_{6}$—$^{23}/_{6}$	I. 96-97-98	101.4	2.8	3	8.4	5.49	0.13	3	0.39
	II. 94-95-99	98.6				5.36			
Western Mediterranean $^{24}/_{6}$—$^{9}/_{7}$	I. 122	101.2	3.3	1	3.3	5.27	0.24	1	0.24
	II. 106-108-112-113-115-116-118-123-125	97.9				5.03			
Tyrrhenian Sea and waters S. E. of Sardinia $^{10}/_{7}$—$^{20}/_{7}$	I. 126-128-131-133-137-138	98.8	1.0	4	4.0	4.97	0.03	4	0.12
	II. 132-134-135-139	97.8				4.94			
Ionian Sea and Sidra Sea $^{20}/_{7}$—$^{26}/_{7}$	I. 143-150	97.2	— 0.1	2	— 0.2	4.63	— 0.05	2	— 0.10
	II. 141-142-144-145-147-148	97.3				4.68			
Tyrrhenian Sea and waters S. E. of Sardinia $^{21}/_{8}$—$^{26}/_{8}$	I. 195-199-202	97.7	0.5	2	1.0	4.68	— 0.02	2	— 0.04
	II. 194-197	97.2				4.70			
Western Mediterranean $^{27}/_{8}$—$^{5}/_{9}$	I. 209-214-217-224	97.1	— 0.2	4	— 0.8	4.72	— 0.05	4	— 0.20
	II. 204-206-207-210-215-218-222-223	97.3				4.77			
Straits of Gibraltar $^{7}/_{9}$—$^{8}/_{9}$	I. 230	97.1	— 1.8	1	— 1.8	5.01	— 0.17	1	— 0.17
	II. 228-229	98.9				5.18			
Atlantic $^{8}/_{9}$—$^{17}/_{9}$	I. 232-234-242	100.3	3.9	2	7.8	5.29	0.15	2	0.30
	II. 231-244	96.4				5.14			
				21	37.7			21	1.66

$$\frac{\Sigma d \cdot v}{\Sigma v} = 1.8\ ^{0}/_{0} \qquad \frac{\Sigma d' v'}{\Sigma v'} = 0.08\ \text{cc.}$$

It may be remarked, that the differences between the averages for the amount of oxygen at the two different periods during the 24 hours follow a certain course, and as we have observations made at different times at the same locality and also observations in different regions at about the same time, we are able to see, whether this course can be referred naturally to the difference in time or the difference in place.

That the variation in the amount of oxygen during the 24 hours is in reality different at the different seasons can be clearly seen from the following comparison, summarized from Table 1.

It is also certain, that the place has some influence on the daily variation in the amount of oxygen in the surface-water. The amplitude is practically 0 for the Ionian Sea and Sidra Sea late in July, but both before and after that time there is a considerable amplitude for the Tyrrhenian

Variation in the relative amount of oxygen during the 24 hours

Region	Before August 1st	After August 1st	Difference
Atlantic	8.0	3.9	4.1
Straits of Gibraltar	2.8	— 1.8	4.6
Western Mediterranean	3.3	— 0.2	3.5
Tyrrhenian Sea etc.	1.0	0.5	0.5

Sea, not to mention the large amplitude which is found in the Atlantic both in June and September.

The explanation of these conditions can scarcely be of a purely physical kind; in the main it must certainly be due to the organic life and the effect of the light; that the daily amplitude decreases on the one hand with the time, from June to September, on the other with the place, from the Atlantic to the Ionian Sea and Sidra Sea, may be explained in both cases by the influence of the rising temperature, if we may presuppose that the amount of plankton also becomes less with rising temperature.

Why we should find a reversed daily period in August—September in the Western Mediterranean and Straits of Gibraltar, must for the present remain unanswered; it is probably due to the incompleteness of the material.

In connection with what we have found for the amount of oxygen in the surface-water of the Mediterranean and the part investigated of the Atlantic, it is of great interest to examine the results arrived at by LEGENDRE (1909 and 1909a) with regard to the daily variation in the amount of oxygen at Concarneau and Arcachon. At both places there is a very distinct daily period, which is much the largest however at Concarneau. The observations at the latter were carried out in August – September 1907 and 1908, at Arcachon in July—August 1909. Regarding the cause of this daily variation in the amount of oxygen LEGENDRE states (1909a p. 27), that it is due to the influence of the light on the algae and that it stands in direct proportion to the richness of the flora.

From the tables given by LEGENDRE it is seen, that the temperature at Concarneau during the period of observation has been considerably lower than at Arcachon; if the difference in temperature in these two cases has had any influence on the amount of the organic life in the sea, it would be in

Table 2. Variation in the relative amount of oxygen during the 24 hours at a depth of 10 meters.

Region	Groups of stations I. Observations between 10 a. m. and 8 p. m. II. Observations between 8 p. m. and 10 a. m.	Relative amount of oxygen in °/₀			
		Average for relative amount of oxygen	d Differences between averages for I and II	v Weights of the differences	$d \times v$
Straits of Gibraltar $^{23}/_{6}$—$^{23}/_{6}$	I. 96 II. 94	101.5 99.8	1.7	1	1.7
Western Mediterranean $^{25}/_{6}$—$^{9}/_{7}$	I. 107-122 II. 112-116-118-125	99.4 99.6	— 0.2	2	— 0.4
Tyrrhenian Sea and waters S. E. of Sicily $^{10}/_{7}$—$^{20}/_{7}$	I. 126-128-131-133-137-138 II. 129-132-134-135-139	97.3 96.5	0.8	5	4.0
Ionian Sea and Sidra Sea $^{22}/_{7}$—$^{26}/_{7}$	I. 143-150 II. 142-144-145-147-148	97.9 96.2	1.7	2	3.4
Tyrrhenian Sea and waters S. E. of Sicily $^{21}/_{8}$—$^{26}/_{8}$	I. 195-199-202 II. 194-197	94.7 96.5	— 1.8	2	— 3.6
Western Mediterranean $^{27}/_{8}$—$^{5}/_{9}$	I. 209-214-217-224 II. 204-206-207-218-222-223	96.9 96.8	0.1	4	0.4
Atlantic $^{8}/_{9}$—$^{16}/_{9}$	I. 242 II. 231	97.2 95.8	1.4	1	1.4
				17	6.9

$$\frac{\Sigma d \cdot v}{\Sigma v} = 0{,}4\ ^{0}/_{0}$$

agreement with what we have concluded regarding the amount of oxygen in the surface-water on the basis of the observations of the "Thor".

It seems in any case as if the variations in the amount of oxygen in the surface-water, for the regions in question and at the times when the observations were made, far exceed the fluctuations which might be due to purely physical causes, changes of temperature and changes in air-pressure, the influence of which I have investigated earlier in the Danish waters (1908).

Unfortunately the observations made in the Mediterranean to the east of Greece are not suited to an investigation of this kind, as they fall in part at awkward times of the day, in part scattered over different regions of the sea.

As mentioned, the daily variation in the amount of oxygen in the surface-water must for the most part be ascribed in the last instance to the influence of the light, but this also implies the possibility, that a daily period may occur in the layers under the surface, in so far as the light is able to make its influence felt there.

Table 2 shows the relative amounts of oxygen at a depth of 10 meters, arranged in a similar manner as for the surface-water in Table 1 and it is seen, that the differences (d) ordinarily are positive, yet their average is only 0.4 % whilst the analogous dimension for the surface was 1.8 %. It should be remarked, however, that the comparison for the two parts of the 24 hours could not be made for the stations in the Atlantic in June for a depth of 10 meters, owing to the absence of sufficient data; in the case of the surface-water these contributed greatly to raise the average of the differences.

For depths of 25 and 50 meters we find the corresponding differences to be respectively — 0.5 % and — 0.6 %.

We must naturally not rely upon the results for 10, 25 and 50 meters giving an exact picture of the daily period in the amount of oxygen, as their numerical basis is too small, yet we are probably entitled to conclude, that the daily period in the relative amount of oxygen (and in the absolute) for the surface-water decreases fairly rapidly downwards, and that at a depth of 10 meters it is several times less than at the surface.

Table 3 (*a*—*p*).

a. Bay of Biscay.

Depth m.	Stat. 80 13. June 1910	Stat. 242 16. Sept. 1910	Stat. 244 17. Sept. 1910
0	103.7	98.3	97.6
10		97.2	
25		97.2	
35		93.0	
50	104.3	91.0	
75		88.8	
100	91.9	90.0	
200	91.3	89.2	
400	83.5	85.7	
600		76.9	
800	69.4	69.6	70.3
875		68.6	
940			69.1
950		66.7	
1000	67.7		
1200	69.7		
1500	76.3		
2000	80.4		

b. Off Cape St. Vincent.

Depth m.	Stat 69 28. Febr. 1909	Stat. 87 17. June 1910	Stat. 89 18. June 1910	Stat. 232 9. Sept. 1910	Stat. 234 10. Sept. 1910
0		111.6	98.3	101.2	101.3
10		112.2			
25		101.2	98.1	95.8	103.0
35				106.3	
50		89.6	101.1	104.3	86.0
100		83.1	91.4	89.3	80.8
200		76.9	75.1	81.5	77.2
400			74.4	75.0	73.9
500					70.0
600		71.7	65.1	65.0	69.6
700			62.6		70.7
800		69.7	71.7	63.8	69.6
875					69.2
900				61.5	
950				62.0	
1000	71.2	69.4	67.6		
1200		69.9			
1250			69.7		
1500		68.9			
2000	76.7				

c. Cadiz Bay

Depth m.	Stat. 65 24. Febr. 1909	Stat. 66 25. Febr. 1909	Stat. 91 18. June 1910	Stat. 92 19. June 1910	Stat.231 8. Sept. 1910
0			99.6	100.9	95.2
10					95.8
25				101.1	99.2
50				102.1	99.5
100			94.3	90.1	85.1
150					81.0
200			82.9	81.7	79.2
300				78.7	76.8
400			76.9	76.9	73.1
500				75.5	
600	70.6		67.4	71.7	66.2
700		77.7			
750				73.7	
800	64.4		63.5		62.6
950					63.4
1000	64.7		64.3		
1200			67.7		
1250	67.2				

d. Straits of Gibraltar west of 5° 30' W. L.

Depth m.	Stat. 61 21. Febr. 1909	Stat. 94 23. June 1910	Stat. 95 23. June 1910	Stat. 96 23. June 1910	Stat. 97 23. June 1910	Stat. 98 23. June 1910	Stat.229 8. Sept. 1910	Stat.230 8. Sept. 1910
0		99.8	100.9	101.3	101.7	101.3	100.0	97.1
10		99.8		101.5			99.0	
25		94.5	102.8	93.9		98.4	102.7	94.6
50			95.9	91.3		95.6	91.4	94.8
60		81.1						
75							86.0	
100			88.6	87.4	90.3	82.2	85.0	83.0
125							84.2	
150			82.2	84.3		77.4	81.5	80.4
160					84.0			
175					84.7		81.1	76.3
180				83.6				
200			75.0		77.2	76.4	79.4	75.4
200					78.7			
200					79.2			
225							79.3	72.6
250					76.5	70.6	76.4	69.2
265			72.7					
275								70.8
300					74.1	69.0	75.5	
400					74.1		70.5	
475							70.5	
500						68.4		
575					71.2			
600	71.1							
700	71.1					69.2		

e. Straits of Gibraltar east of 5° 30' W. L.

Depth m.	Stat. 60 21. Febr. 1909	Stat. 99 23. June 1910	Stat. 228 7. Sept. 1910
0		95.1	97.7
25		94.2	92.5
50		87.8	82.7
75			78.7
100		90.8	74.4
125		74.4	71.2
150		67.7	68.9
200		66.3	63.5
250		67.7	64.2
300		68.2	65.1
400		68.3	66.9
500		70.5	70.2
600	67.5	71.4	
700			71.3
850	70.5		
1000		69.0	

f. Off Cape de Gata

Depth m.	Stat. 54 19. Febr. 1909	Stat. 106 24. June 1910	Stat. 224 5. Sept. 1910
0		99.4	97.4
10			97.7
25		102.7	103.7
35			108.7
50		89.8	103.9
75		80.6	95.0
100		74.4	90.6
150		84.9	88.3
200		84.2	86.6
250			83.1
300		81.7	79.7
400		76.8	72.2
500			67.2
600	75.1	73.2	68.0
800	75.4	72.5	
950			71.5
1000	75.8	73.0	
1400	75.6		

g. Between Cape de Gata and Oran.

Depth m.	Stat. 107 25. June 1910	Stat. 223 5. Sept. 1910
0		98.1
10	98.3	98.0
25		107.0
50	95.6	102.5
75	82.1	93.6
100	74,5	88.5
125		85.7
150	74.4	77.7
200	71.4	73.1
250		69.6
300	69.4	68.1
400	69.0	65.8
500	70.1	
600	70.8	67.9
800	72.7	
950		70.7
1000	73.2	
1500	74.9	76.4
2000	76.9	77.1

h. Off Oran.

Depth m.	Stat. 51 17. Febr. 1909	Stat. 52 18. Febr. 1909	Stat.108 25. June 1910	Stat.222 4. Sept. 1910.
0			98.3	99.3
10				96.3
20				107.4
25			103.8	107.2
50			100.0	98.1
75				80.1

Depth m.	Stat. 51 17. Febr. 1909	Stat. 52 18. Febr. 1909	Stat.108 25. June 1910	Stat.222 4. Sept. 1910
100			77.1	76.4
125				78.6
150			73.2	
200			72.0	76.6
300			69.0	74.5
400			70.6	68.8

Depth m.	Stat. 51 17. Febr. 1909	Stat. 52 18. Febr. 1909	Stat.108 25. June 1910	Stat.222 4. Sept. 1910
500				68.2
600	70.8	70.6	71.3	70.6
800	72.5			71.8
1000	73.6	74.8	73.9	
1500	75.6		75.8	
2000	76.6	77.1		

i. Between Oran and Algiers.

Depth m.	Stat. 50 16. Febr. 1909	Stat.112 26. June 1910
0		97.4
10		100.2
25		104.5
50		79.4
75		79.5
100		78.3
150		79.0
200		75.7
250		74.2
300		71.6
400		74.1
600		72.7
800		71.7
1000	74.3	74.3
1200		74.6
1250	74.9	
1500	76.3	77.3
2000	77.1	79.9

k. Off Algiers.

Depth m.	Stat. 47 8. Febr. 1909	Stat.113 28. June 1910	Stat.218 2. Sept. 1910
0		99.4	97.6
10			98.6
15			102.2
20			109.1
25		101.6	104.3
50		105.4	93.1
75			88.2
100		82.0	83.0
125			83.4
150		80.2	79.9
175			80.4
200		72.9	77.6
250		69.3	
300		69.0	72.2
400		71.1	70.7
600	71.2		71.3
950			72.4
1000	74.2		
1500	76.1		
2000	76.8		

l. East of the Balearic Isles.

Depth m.	Stat.116 29. June 1910	Stat.206 28. Aug. 1910
0	95.6	96.8
10	95.2	96.7
20	95.4	
25	98.1	98.7
35	100.6	104.4
40		108.7
50	99.3	112.8
75	97.0	103.3
100	83.4	88.6
150		79.4
175		77.5
200	78.6	85.4
250		80.0
300	72.9	74.9
400	71.0	70.5
600	71.4	70.3
800	72.5	70.3
1000	73.8	71.0
1250		71.5
1500	75.1	77.1
2000		80.2
2400	78.7	
2500		78.4

m. S. E. coast of Sardinia.

Depth m.	Stat. 42 2. Febr. 1909	Stat.132 14. July 1910	Stat.202 26. Aug. 1910
0		98.8	98.3
10		99.2	94.7
15		100.8	
20		103.4	
25		103.9	108.2
50		100.0	98.6
75		92.2	99.3
100		85.1	91.7
125		84.8	85.1
150		81.6	82.5
200		79.3	78.1
300		74.8	74.1
400		73.4	73.8
600	73.2	73.2	71.1
750			69.5
800	72.2	71.4	
1000	71.7	71.0	
1200		71.0	
1500		71.3	

n. Tyrrhenian Sea.

Depth m.	Stat. 24 16. Jan. 1909	Stat.129 12. July 1910	Stat 199 25. Aug. 1910
0			98.3
10		93.5	97.7
25		96.4	105.3
35			107.3
50		100.9	109.2
75		97.4	102.3
100		87.8	91.6
150		77.4	81.9
200		76.0	79.7
300		75.5	75.9
400		75.0	74.4
500		73.8	
600	75.4	73.1	73.6
800	75.3	72.6	
1000	72.6	71.7	71.9
1200		71.3	
1250	72.8		
1500	72.7	71.5	
1800	73.7		
2000	73.6	71.7	
2130	74.4		
2500		72.0	
3200		72.8	

o. Off Monaco.

Depth m	Stat. 35 28. Jan. 1909	S/s Eider 0968 18. Febr. 1910	S/s Eider 0981 2. March 1910	"Golfe de Gênes" 1. June 1910	Au large de Monaco 13. June 1910	St. 122 2. July 1910
0		95.4	96.9			101.2
10						100.4
15						104.7
25				94.6		98.6
50		101.5	97.4	83.8		86.7
75						87.4
100		87.5	94.9			81.3
125						77.7
150		94.7	101.4			72.3
200		96.7	87.0	76.6	90.3	72.2
250		90.1	79.2			74.0
300		80.6	79.2	76.4	74.6	72.5
350		76.4	84.4			
400		75.9	75.8	59.6		72.2
450		74.7	75.4	74.7		
500		74.7	76.1	75.1	72.8	72.4
600	74.9	72.8	76.5	76.2	73.4	73.5
700				77.7	74.5	
800	74.5	72.1	78.0			74.8
1000	75.2	75.0	78.4			76.8
1200				78.0		
1250	75.2					79.6
1400					78.5	
1460			78.9			
1500	77.5					
1800				78.0		
2000	76.6					

p. North-east of Corsica.

Depth m.	Stat. 32 22. Jan. 1909	Stat.126 10. July 1910
0		98.2
10		98.4
25		98.7
40		102.5
50		102.3
75		99.1
100		96.2
150		88.2
175		86.8
200		85.8
300		78.1
400		77.4
500		74.1
580		71.4
600	76.4	

III. Variation in the amount of oxygen with the season of the year.

A view over the variation in the amount of oxygen with the seasons can be obtained from Table 3 (a-p). The stations are arranged in groups and within each group the observations for the same depth are placed in the same line. As it is also desired to ascertain whether the amount of oxygen varies with the seasons in the deeper layers as well as at the surface, the groups are so chosen, that they form comparatively restricted areas, so that the difference in place may have the least possible influence on the amounts of oxygen within the same group.

Even if this supposition is not quite fulfilled yet a distinct regularity can be seen in the variation of the amount of oxygen with the season of the year. If we examine the relative amounts of oxygen given for the upper layers in Table 3, we notice at once, that whilst almost 100 % is found at the very surface, supersaturation is rather prevalent at a certain depth below this. To be able to compare the maxima of supersaturation in the periods June—July and August—September a summary of these maxima for Mediterranean stations mentioned in Table 3 is given in Table 4 both for the relative amount of oxygen and for the absolute.

Table 4.

Region	June—July				August—September			
	Stat.	Depth m.	Relative amount of oxygen	Absolute amount of oxygen	Stat.	Depth m.	Relative amount of oxygen	Absolute amount of oxygen
Off Cape de Gata	106	25	102.7	5.71	224	35	108.7	5.85
Between Cape de Gata and Oran					223	25	107.0	5.58
Off Oran	108	25	103.8	5.68	222	20	107.4	5.73
Between Oran and Algiers	112	25	104.5	5.78				
Off Algiers	113	50	105.4	5.85	218	20	109.1	5.88
East of Balearic Isles	116	35	100.6	5.50	206	50	112.8	6.07
Ligurian Sea	122	15	104.7	5.97				
S. E. coast of Sardinia	132	25	103.9	5.81	202	25	108.2	5.79
Tyrrhenian Sea	129	50	100.9	5.64	199	50	109.2	6.04
N. E. of Corsica	126	40	102.5	5.56				

As will be seen, the supersaturation which occurs at the depths mentioned is quite considerable. The maximum for the relative amounts of oxygen is greater in the second part of the summer than in the first, but this also applies on the whole for the absolute amounts. In all probability the supersaturation which occurs is due to the production of oxygen by plankton organisms, and the increase which has occurred between the two seasons can also be explained naturally in the same way.

For the sake of convenient comparison of the amounts of oxygen in the same depth at different times the details of Table 5 have been extracted from Table 3. For depths down to 400 m. the difference is shown between the averages for the amounts of oxygen found within each group at the two seasons, June—July and August—September; lastly, in the lower part of Table 5 the differences for the same depth are brought together to form averages applying to the three large regions, the part of the Atlantic investigated, Straits of Gibraltar and the Mediterranean as far as Sicily.

It is seen from this Table, that the relative amount of oxygen has decreased from June to September from the surface down to 400 m. in the Atlantic. In the Straits of

Gibraltar, similarly, the amount of oxygen has decreased from June to September from the surface down to 100 m.; deeper down there is alternately an increase and a decrease, to which, however, we must ascribe but little importance, owing to the complicated hydrographical conditions in the Straits of Gibraltar.

Table 5. The increase (+) or decrease (—) in the relative amount of oxygen from June—July to August—September.

	Region	0	10	25	50	100	150	200	300	400 m.
I	Bay of Biscay	— 5.7			—13.3	— 1.9		— 2.1		2.2
I	Off Cape Vincent	— 3.7		— 0.2	— 0.2	— 2.2		3.3		0.0
I	Cadiz Bay	— 5.0		— 1.9	— 2.6	— 7.1		— 3.1	— 1.9	— 3.8
II	Straits of Gibraltar W. of 5° 30′	— 2.5	— 1.7	1.2	— 1.2	— 3.1	— 0.4	0.1	4.0	— 3.6
II	do. E. of 5° 30′	2.6		— 1.7	— 5.1	—16.4	1.2	— 2.8	— 3.1	— 1.4
III	Off Cape de Gata	— 2.0		1.0	14.1	16.2	3.4	2.4	— 2.0	— 4.6
III	Between Cape de Gata and Oran		— 0.3		6.9	14.0	3.3	1.7	— 1.3	— 3.2
III	Off Oran	1.0		3.4	— 1.9	— 0.7		4.6	5.5	— 1.8
III	Off Algiers	— 1.8		2.7	—12.3	1.0	— 0.3	4.7	3.2	— 0.4
III	East of Balearic Isles	1.2	1.5	0.6	13.5	5.2		4.6	2.0	— 0.5
III	S. E. coast of Sardinia	— 0.5	— 4.5	4.3	— 1.4	6.6	0.9	— 1.2	— 0.7	0.4
III	Tyrrhenian Sea		4.2	8.9	8.3	3.8	4.5	3.7	0.4	— 0.6
I	Atlantic	— 4.8		— 1.0	— 5.4	— 3.7		— 0.6	— 1.9	— 0.5
II	Straits of Gibraltar	0.0	— 1.7	— 0.2	— 3.2	— 9.8	0.4	— 1.4	0.5	— 2.5
III	Mediterranean from Gibraltar to Sicily	— 0.4	0.2	3.5	3.9	6.6	2.4	2.9	1.0	— 1.5

For the part of the Mediterranean which lies between the Straits of Gibraltar and Sicily, on the other hand, we find a greater regularity; the averages show, that the relative amount of oxygen is very nearly the same in both periods, June—July and August—September, at the surface and a depth of 10m.; but it has become greater in the course of the summer for all depths between 25 and 300m.; with few exceptions this also applies to the separate groups of stations.

At a depth of 400 m., however, the conditions change character; all the groups investigated with but one exception show a decrease in the relative amount of oxygen.

Table 6. The increase (+) or decrease (—) in the absolute amount of oxygen from June—July to August—September.

	Region	0	10	25	50	100	150	200	300	400 m
I	Bay of Biscay	— 0.48			— 0.80	— 0.13		— 0.14		0.13
I	Off Cape Vincent	— 0.45		— 0.25	— 0.01	— 0.10		0.21		0.01
I	Cadiz Bay	— 0.49		— 0.20	— 0.15	— 0.32		— 0.14	— 0.06	— 0.17
II	Staits of Gibraltar W. of 5° 30′	— 0.40	— 0.43	— 0.22	— 0.05	— 0.13	0.04	0.08	0.26	— 0.18
II	do. E. of 5° 30′	0.00		— 0.15	— 0.30	— 0.83	0.07	— 0.15	— 0.18	— 0.09
III	Off Cape de Gata	— 0.32		— 0.43	0.63	0.84	0.10	0.07	— 0.11	— 0.28
III	Between Cape de Gata and Oran		— 0.25		0.18	0.69	0.13	0.09	— 0.08	— 0.19
III	Off Oran	— 0.11		0.18	— 0.07	— 0.04		0.28	0.34	— 0.11
III	Off Algiers	— 0.29		0.08	— 0.60	0.05	— 0.02	0.29	0.19	— 0.03
III	East of Balearic Isles	— 0.17	— 0.26	— 0.46	0.50	0.26		0.27	0.13	— 0.02
III	S. E. coast of Sardinia	— 0.32	— 0.59	— 0.02	— 0.09	0.36	0.06	— 0.08	— 0.04	0.03
III	Tyrrhenian Sea		— 0.05	0.34	0.40	0.23	0.29	0.24	0.01	— 0.04
I	Atlantic	— 0.46		— 0.22	— 0.32	— 0.18		— 0.02	— 0.06	— 0.01
II	Straits of Gibraltar	— 0.20	— 0.43	— 0.18	— 0.18	— 0.48	0.06	— 0.04	0.04	— 0.14
III	Mediterranean from Gibraltar to Sicily	— 0.24	— 0.29	— 0.05	0.14	0.34	0.11	0.17	0.06	— 0.09

As the relative amount of oxygen may change without the absolute amount doing so, it will be of interest to see, how far the latter varies and Table 6 shows the increase of absolute amount in cc., arranged in the same manner as the relative amount in Table 5.

We see from this Table, that the absolute amount of oxygen in the surface-water and at a depth of 10 m. has decreased considerably; if we estimate the amount of oxygen necessary for saturation to be 5 to 6 cc., the differences in the absolute amount of oxygen correspond to about 8%, 4% and 4% for the surface-water in the three regions respectively. In the same time the temperature has risen by 2 to 3 degrees, so that the amount of oxygen in the surface-water becomes less from this cause and for the stations in the Mediterranean just so much is given off, that the surface remains saturated constantly with oxygen, whilst for the Atlantic stations, on the other hand, there seems to be a greater decrease in the absolute amount of oxygen than would correspond with the rise in temperature. As can be seen from Table 3a, b and c the water in June has also been considerably oversaturated with oxygen, probably arising from the activities of plant-life.

For the depths from 50—400 m. Table 6 shows, that the increase of the absolute amounts of oxygen has the same sign as those for the relative amounts (Table 5) with only a single exception; an actual change in the amount of oxygen must therefore have taken place in the direction indicated by the signs.

Table 7. Rise (+) or fall (—) of the temperature from June—July to August—September.

	Region	0	10	25	50	100	150	200	300	400
I	Bay of Biscay	1.68			0.04	0.17		0.18		0.19
	Off Cape Vincent	2.88		2.77	0.02	— 0.18		— 0.14		— 0.15
	Cadiz Bay	2.76		1.06	0.07	— 0.62		— 0.48	— 0.59	— 0.62
II	Straits of Gibraltar W. of 5° 30′	3.18	4.06	3.35	— 0.15	— 0.65	— 0.39	— 0.70	0.18	— 0.38
	do. E. of 5° 30′	1.62		0.62	0.02	— 1.07	0.01	— 0.02	— 0.02	— 0.02
III	Off Cape de Gata	2.78		5.66	1.79	1.54	1.59	0.98	0.04	0.05
	Between Cape de Gata and Oran		3.30		2.58	1.98	1.17	0.21	— 0.04	— 0.01
	Off Oran	1.88		— 0.09	— 0.26	0.06	0.04	— 0.10	— 0.15	0.06
	Off Algiers	2.54		0.71	— 0.87	0.11	— 0.06	— 0.17	— 0.07	0.08
	East of Balearic Isles	3.00	4.57	6.12	2.38	0.13		— 0.03	— 0.31	— 0.16
	S. E. coast of Sardinia	4.04	4.75	2.70	0.19	0.30	— 0.08	0.01	— 0.03	— 0.13
	Tyrrhenian Sea		3.44	1.52	0.63	— 0.03	— 0.32	— 0.34	0.01	0.02
I	Atlantic	2.44		1.92	0.04	— 0.21		— 0.15	— 0.59	— 0.19
II	Straits of Gibraltar	2.40	4.06	1.98	— 0.06	— 0.86	— 0.19	— 0.36	0.08	— 0.20
III	Mediterranean from Gibraltar to Sicily	2.85	4.01	2.77	0.92	0.58	0.39	0.08	— 0.08	— 0.01

An investigation like the present, which is based on averages, as in Tables 5 and 6, naturally assumes the character of a summary, as the averages for the amounts of oxygen and the differences between them refer to the water present at the stations when the observations were made; at a few of the stations this water has been of different character in the depths mentioned, which is seen in the changes which have taken place in the temperature and salinity between the times of observation. To obtain a view over these changes, Tables 7 and 8 have been drawn up to show increasing of the average temperatures and average salinities, analogous to Tables 5 and 6 which showed increasing of the relative and the absolute amounts of oxygen.

It appears distinctly from these tables, that "Off Cape de Gata" and "Between Cape de Gata and Oran" the water at depths of 50—200 m. has been quite different at the two periods and this can also be readily seen from the main Tables p. 61 and 69 for the stations in question, 106, 107 and 223, 224; at the depths mentioned the water has been warmer and less saline in September than in June. The explanation of this must be, that in September the stretch Oran—Cape de Gata has been to a greater degree

Table 8. The increase (+) or decrease (—) in the salinity from June—July to August—September.

	Region	0	10	25	50	100	150	200	300	400 m.
I	Bay of Biscay	— 0.04			— 0.01	0.03		0.00		0.00
	Off Cape Vincent	0.13		0.13	— 0.02	— 0.04		— 0.01		— 0.02
	Cadiz Bay	0.09	0.22	0.11	— 0.07	— 0.18		— 0.10	— 0.11	— 0.12
II	Straits of Gibraltar W. of 5° 30′	0.21	0.25	0.15	— 0.02	— 0.20	— 0.71	— 0.96	— 0.76	0.16
	do. E. of 5° 30′	0.19		0.27	0.25	— 0.25	— 0.02	0.01	0.04	0.03
III	Off Cape de Gata	0.08		0.03	— 0.29	— 1.21	— 1.46	— 0.65	— 0.05	— 0.01
	Between Cape de Gata and Oran	— 0.36	— 0.42	— 1.17	— 1.21	— 1.56	— 1.01	— 0.16	— 0.08	0.01
	Off Oran	0.11	0.11	0.00	— 0.11	— 0.29	0.00	— 0.02	— 0.06	0.01
	Off Algiers	0.12		— 0.25	— 0.29	0.06	0.05	— 0.09	— 0.05	0.01
	East of Balearic Isles	— 0.20	— 0.13	0.38	0.15	0.10		— 0.05	— 0.08	— 0.05
	S. E. coast of Sardinia	0.20	0.07	— 0.27	— 0.42	— 0.10	— 0.12	— 0.06	— 0.03	0.02
	Tyrrhenian Sea	0.29	0.29	0.15	0.00	— 0.03	— 0.16	— 0.07	0.02	0.02
I	Atlantic	0.06	0.22	0.12	— 0.03	— 0.06		— 0.04	— 0.11	— 0.05
II	Straits of Gibraltar	0.20	0.25	0.21	0.12	— 0.23	— 0.36	— 0.48	— 0.36	0.10
III	Mediterranean from Gibraltar to Sicily	0.06	0.06	— 0.09	— 0.23	— 0.37	— 0.44	— 0.18	— 0.09	0.01

Table 9.

		Extremes for temperature			Extremes for salinity			Average for relative amount of oxygen		
		Jan. Febr. March	June July	Aug. Sept.	Jan. Febr. March	June July	Aug. Sept.	Jan. Febr. March	June July	Aug. Sept.
Biscay	Stat.: 80 242 244 Date: 13/6 10 16/9 10 17/9 10		9.53 10.07	9.81 10.33		35.73 35.77	35.55 35.81		68.6	70.2
e St. Vincent	Stat.: 69 87 89 232 234 Date: 28/2 09 17/6 10 18/6 10 9/9 10 10/9 10	10.89 11.69	10.74 12.27	10.34 12.27	35.68 36.40	35.64 36.42	35.68 36.31	71.2	68.3	66.4
ay	Stat.: 65 66 91 92 231 Date: 24/2 09 25/2 09 18/6 10 19/6 10 8/9 10	10.24 12.15	10.30 12.75	10.53 10.89	35.57 36.94	35.61 36.92	35.68 35.95	69.4	68.1	64.1
of Gibraltar West of W. L.	Stat.: 61 98 Date: 21/2 09 23/6 10	12.95 12.97	12.95		38.37 38.37	(38.37)		71.1	69.2	
of Gibraltar East of W. L.	Stat.: 60 99 228 Date: 21/2 09 25/6 10 7/9 10	12.91 13.00	12.83 12.85	12.77	38.37 38.40	38.37 38.37	38.39	69.0	70.2	71.3
e de Gata	Stat.: 54 106 224 Date: 19/2 09 24/6 10 5/9 10	12.92 12.95	12.89 12.92	12.88 12.92	38.35 38.39	38.37 38.37	38.38 38.40	75.4	72.9	69.7
Cape de Gata and	Stat.: 107 223 Date: 25/6 10 5/9 10		12.88 12.93	12.92 12.93		38.37 38.39	38.39 38.39		72.2	69.3
a	Stat.: 51 52 108 222 Date: 17/2 09 18/2 09 25/6 10 4/9 10	12.91 13.00	12.88 12.90	12.82 12.90	38.39 38.44	38.37 38.39	38.38 38.39	72.5	72.6	71,2
Oran and Algiers	Stat.: 50 112 Date: 16/2 09 26/6 10	12.91 12.94	12.86 12.89		38.37 38.40	38.35 38.37		74.3	72.9	
ers	Stat.: 47 218 Date: 8/2 09 2/9 10	12.91 12.99		12.84 12.88	38.37 38.39		38.38 38.39	72.7		71.8
Balearic Isles	Stat.: 116 206 Date: 29/6 10 28/8 10		12.86 12.97	12.83 12.89		38.37 38.39	38.36 38.38		72.6	70.5
aco	Stat.: 35 S/S 0968 Eider 0981 S/S Eider "Golfe de Gênes" de Monaco Au large 122 Date: 28/1 09 18/2 10 2/3 10 1/6 10 13/6 10 2/7 10	12.86 13.41	12.86 13.06		38.42 38.57	38.37 38.46		75.3	75.3	
st of Sardinia	Stat.: 42 132 202 Date: 2/2 09 14/7 10 26/8 10	13.19 13.64	13.24 13.55	13.36 13.49	38.49 38.64	38.48 38.55	38.51 38.54	72.4	71.9	70.3
ian Sea	Stat.: 24 129 199 Date: 16/1 09 12/7 10 25/8 10	13.49 13.84	13.42 13.70	13.25 13.55	38.51 38.64	38.53 38.60	38.49 38.55	74.4	72.5	72.8
Corsica	Stat.: 32 126 (Depth 580) Date: 22/1 09 10/7 10	13.50	13.43		38.60	38.53		76.4	71.4	

than in June filled with water, which has come in through the Straits of Gibraltar from the Atlantic; this water has thus brought with it a greater amount of oxygen.

The generally larger amounts of oxygen for the Mediterranean in August—September at the depths 100—300 m., are probably due in part to the activities of plant-organisms, in part possibly to the supersaturation which is found in depths down to 100 m., as the currents and waves lead to a partial mixing of the layers; diffusion has also played some part possibly.

The variation in the relative amount of oxygen with the seasons, for depths between 600 and 1000 meters, can be seen from the Tables 3 (a—p), but can be more readily grasped from Table 9, where the stations from June—July and August—September are arranged in the same groups as before. Further, the Table also contains groups of stations from the winter of 1909, so that a comparison of the amounts of oxygen can also be made between the seasons mentioned earlier and January, February and March, for the depths noted. In addition to the amounts of oxygen the extremes of temperature and salinity corresponding to each average for the amount of oxygen are also given in Table 9.

In depths greater than 600 meters the averages for the amount of oxygen show in most cases a decrease from January—February—March to August—September, for the stations in the Atlantic as well as for those in the Straits of Gibraltar and Mediterranean. In the Atlantic and Straits of Gibraltar, however, the hydrographical conditions are fairly complicated, as can be seen from the great difference in the extremes for the temperature and salinity, so that such a summary of the averages for these regions does not yield a complete picture of the variation in the amount of oxygen for water of a definite kind.

For the stations in the Mediterranean the extremes for the temperature and salinity are much less divergent and as the variation in the amount of oxygen has the same character for such a large region, we may believe, that the lack of oxygen has arisen from a consumption in the layers in question.

On the basis of Table 9 we may construct the following Table on the variation in the amount of oxygen with the season for the different regions.

Table 10.

Region	Decrease in the amount of oxygen at 600—1000 m. From January—February to June—July	From June—July to August—September
Alboran Sea	1.2	2.5
Balearic Sea	0.9	1.3
Tyrrhenian Sea	1.9	— 0.3

If, for the regions mentioned in the above Table, we calculate the average for the decrease in the amount of oxygen for the whole period January—September we obtain 2.5 %.

These results can only give some notion, however, of the extent of the variation, as the waters for which the comparison could be made are not sufficiently representative of the whole regions to which the averages have been made to apply.

As we shall see later, the amount of oxygen in the deeper layers differs with the place, but this also applies to its variation with the time, as can be seen from Table 9 for the layer between 600 and 1000 meters. The three regions which are indicated by "Off Cape de Gata", "Between Cape de Gata and Oran" and "Off Oran", represent three parts of a section from Cape de Gata to Oran. Table 9 shows, that the decrease in the amount of oxygen with the time is greatest in the northern part, less in the central part, for which however we only have observations from June and September, and lastly least in the southern part. If we consider the whole period February—September, we see from the observations, that the decrease in the amount of oxygen is ca. 4 times as great in the northern part as in the southern.

The extremes for the temperature and salinity show that the conditions in this regard have been very uniform, yet it must be remembered that the difference for the temperature and salinity in deep water is small, and as we have seen, that great hydrographical changes have occurred in the upper layers just in this section, there is the possibility that this may also be the case in the deeper layers, even though we may not be able to detect it in the variation of temperature and salinity; in such a case we are hardly at liberty to conclude, that the difference actually found in the decrease for the amount of oxygen was due to a real decrease in the consumption of oxygen.

The decrease in the amount of oxygen with the time seems on the whole to be relatively small on the southern coast of the Balearic Sea; thus, it is less "Between Oran and Algiers" and "Off Algiers" than "East of the Balearic Isles".

In the Tyrrhenian Sea there is a decrease in the amount of oxygen from January to July, but a slight rise from July to August; this however is probably simply a "chance".

On the "South-east coast of Sardinia", which lies on the boundary between the Balearic Sea and the Tyrrhenian Sea, there is a regular decrease, but not so great either as to the east of the Balearic Isles and at the northern coast of the Alboran Sea.

The great decrease to the "North-east of Corsica" is based on only two determinations, the one at a depth of 580 m., the other at 600 m. and this should not be forgotten even if the decrease in the amount of oxygen here is great.

In the layers below 1000 meters the variation in the amount of oxygen with the time is less regular; the observations are also much fewer than for between 600 and 1000 meters, so that no general conclusions can be drawn. We may remark, however, that there is an increase in the amount of oxygen from February to June "Between Oran and Algiers" and a specially high value at a depth of 2000 m. in June (79.9 %), and further, that the amount of oxygen deeper than 1000 m. in the Tyrrhenian Sea decreases from January to July in the same way as between 600 and 1000 m.

If we endeavour to summarize what we have found regarding the variation in the amount of oxygen with the seasons, we obtain the following picture. In the part of the Mediterranean considered the uppermost layers down to ca. 25 m. remain very nearly saturated with oxygen from the atmosphere; below this layer, in depths from ca. 25 to 75 m., supersaturation is frequently found and this we may suppose to arise from the organic activities of oxygen-producing species of the plankton; these supersaturations probably occur mainly in the summer time, they are everywhere most marked in the latter part of the summer.

From 100 to 300 meters the amount of oxygen is on the increase from June to September, but on the other hand on the decrease in 400 m. and below. The explanation of the increase in the amount of oxygen in the layers between 100 and 300 m. is probably, that the oxygen is carried down from the overlying layer by mixing or is developed directly; on the other hand, it is probable that there is a consumption of oxygen in the layers below, either by living organisms or by dead organisms, which sink down from the upper layers.

In the material dealt with so far observations are only present from June to September for the uppermost 600 meters, whereas for the layers below this depth we also have winter observations. Thus, it is not possible to form any picture of the changes in the amount of oxygen for the uppermost 600 meters during the transition from winter to spring, when great hydrographical changes occur. It is only for the Ligurian Sea, that we have a series of observations in the upper layers for the cold period of the year. These come from Monaco and were made under the direction of Dr. Richard; they are recorded in Table 3 along with the stations taken by the "Thor" in the same waters.

From Table 3*o* "Off Monaco" we may note, that considerable changes have occurred in the amount of oxygen between the two epochs, 18th of February and March 2nd; these changes may be considered to have arisen by new water replacing, between the two dates, what was present on February 18th. Similar conditions occur in the period from the 1st to 13th June, and when such rapid variations may occur, we can hardly conclude very much more from these single series than simply that such rapid variations do occur. It deserves to be remarked, however, that no essential supersaturation was found in the uppermost layers in the cold period of the year, but if such occurred, for example, at a depth of 15 m. and not at other depths, we should not have noticed it. A very low amount of oxygen, 59.6 %, was observed at a depth of 400 m. on June 1st 1910.

For the layers below 600 meters, a great increase in the amount of oxygen has occurred from the 18th of February to the 2nd of March, possibly due to the water in these layers being mixed with surface-water, which has been carried down by the cooling process of winter. After the 2nd of March there is on the whole a decrease in the amount of oxygen between 600 and 1000 m., corresponding with what we have earlier found for the other places at these depths; on the other hand, the changes are not great in depths below 1000 m., after the increase has taken place on the 2nd of March.

IV. Variation in the amount of oxygen with the locality.

a. Atlantic.

We have seen in the foregoing how great variations in the amount of oxygen may arise from causes, which for the present at any rate cannot be calculated, and we can thus also see, with what certainty we may consider an amount of oxygen found at a definite place as characteristic for that place.

Where the conditions are analogous with those found in the investigated part of the Atlantic and Western Mediterranean, it is hardly necessary to discuss the changes in the amount of oxygen in the surface and uppermost layers from place to place. Most interest is attached to the minimum found in 600—1000 m. and to the amount of oxygen in the layers below this.

Before we discuss the amount of oxygen in these layers at the Atlantic stations, it is necessary and natural to refer to the large number of oxygen analyses made by Dr. Brennecke (1909, p. 51) on the voyage of S. M. S. "Planet". Among the stations of the "Planet", 1, 2 and 3 fall in the same region as the Atlantic stations of the "Thor"; they were investigated in January and February 1906 and special interest is attached to a comparison with the stations of the "Thor", which were investigated in June 1910 and February 1909; they are therefore included in Table 11 p. 224, where the amounts of oxygen and the corresponding values for the temperature, salinity and σ_t are noted for the depths where the oxygen minimum occurs. Comparing the stations of the "Planet" with those of the "Thor", which lie in the neighbourhood thereof, we obtain the following result.

"Planet"		"Thor"		
Station	Amount of oxygen in minimum	Station	Amount of oxygen in minimum	Difference
1	70.2	80	67.7	2.5
2	67.9	81	67.5	0.4
3	62.7	65	64.4	— 1.7

Although the stations of the "Planet" and "Thor" do not lie exactly at the same spots and the difference in time is ca. 4 years, the difference between the

minimum values for the amount of oxygen is at most 2.5 %, thus a difference of the same order as that we have already found in the variation for the amount of oxygen with the seasons.

The temperature, salinity, amount of oxygen and σ_t for the different depths at stations 80 and 87 are represented in the figures 1 and 2; it will be seen, how the minimum for the amount of oxygen falls almost at the same place as the maximum for the salinity. A similar distribution is found at the other stations, but sometimes there may be two minima for the amount of oxygen.

The distribution of the amount of oxygen in the investigated part of the Atlantic can be seen most readily from the sections drawn through the stations; these are:

Section	along the S. W. coast of Spain (87, 89, 92 and 94) June 1910	fig. 3
—	through Straits of Gibraltar (65, 61, 60 and 59) Febr. 1909	— 4
—	— — — (91, 98 and 99) June 1910	— 5
—	— — — (231, 230 and 228) Sept. 1910	— 6
—	across — — (94, 95, 97 and 96) June 1910	— 7
—	— — — (230 and 229) Sept. 1910	— 8

It may be mentioned that in these and the following sections the lines representing the bottom are only approximately constructed.

It appears from the sections, that the most characterstic point about the distribution of the amount of oxygen in the region outside the Straits of Gibraltar is the minimum at a depth of ca. 900 meters. It occurs in a somewhat complicated form in the section along the coast of Spain, but its situation and dimension is very uniform in the three sections through the Straits of Gibraltar; these three sections are almost exactly at the same place, but they were taken at different times, February, June and September.

As already mentioned in the introduction, a similar minimum for the oxygen is found at a somewhat less depth in the Mediterranean; this minimum is also seen in the three sections through the Straits of Gibraltar.

It is well-known, that an outflowing bottom-current flows through the Straits of Gibraltar, which can be detected by an increase in the salinity along the coast of Spain. Since, now, the maximum for the salinity in deep water occurs at about the same place as the oxygen minimum, it might be imagined, that the minimum in the Atlantic water is due in the main to a small amount of oxygen in the outflowing Mediterranean water.

Such a conclusion, however, would only apply to a very restricted area outside the Straits of Gibraltar. From the sections 4, 5 and 6 through the Straits of Gibraltar we see, that at the three periods of the year when the observations were made, the water with smaller, relative amount of oxygen than 69 % is not proceeding from the Mediterranean out into the Atlantic and from the sections figs. 10 and 11, further, that water with much less oxygen than 65 % is scarcely to be found in the Alboran Sea. To this is added, that when the amount of oxygen at the stations investigated in the Alboran Sea is less than 70 %, the salinity is greater than 38 ‰; after flowing out of the Mediterranean the salinity of this water is reduced considerably by mixing with Atlantic water with a salinity of ca. 35.5 ‰.

The values for the temperature, salinity, amount of oxygen and σ_t for the depths at which the amount of oxygen is a minimum, are shown in table 11.

For the places where the oxygen minimum occurs at the Atlantic stations, Table 11 shows, that the water consists only for a very small part of Mediterranean water with 38 ‰ salinity, but that the relative amount of oxygen is on the whole considerably less than 70 %, so that we must imagine either the existence of a minimum of a little less than 70 % in the Atlantic water itself or a great consump-

tion of oxygen during the passage of the Mediterranean water through the Straits of Gibraltar or after mixing has occurred.

Table 11. Temperature, salinity, amount of oxygen and σ_t at the Atlantic stations, at the depth where the amount of oxygen shows a minimum.

Station		Depth	Temperature	Salinity	Amount of oxygen	σ_t
"Planet" **	1	800	10.0	35.70	70.2	27.52
—	2*	800	10.7	35.79	67.9	27.48
—	3	600	10.9	35.61	62.7	27.28
"Thor"	65	800	10.73	35.84	64.4	27.50
—	80	1000	9.53	35.77	67.7	27.65
—	81	1000	10.84	36.02	67.5	27.62
—	87	1000	12.00	36.42	69.4	27.71
—	87*	1500	10.82	36.29	68.9	27.84
—	89	700	10.61	35.73	62.6	27.44
—	89	1000	11.66	36.38	67.6	27.75
—	91	800	10.64	35.82	63.5	27.50
—	92	600	12.19	36.60	71.7	27.81
—	231	800	10.79	35.88	62.6	27.51
—	232	900	10.34	35.95	61.5	27.65
—	234	600	11.60	35.95	69.6	27.42
—	234*	875	11.97	36.31	69.2	27.63
—	242*	950	9.94	35.81	66.7	27.61

* These results are from the greatest depth at which sample were taken at the station.

** Situation of the stations of the "Planet":

No. 1 46° 52′ N. Lat., 7° 4′ W. Long., near "Thor's" Stat. 80
„ 2 41° 19′ „ „ 11° 31′ „ „ „ „ „ 81
„ 3 35° 58′ „ „ 7° 54′ „ „ „ „ „ 65

As the oxygen minimum for the Atlantic stations is so uniform, however, and we have seen, that the changes occurring in the course of some months are in general small, we may conclude, that there must be a minimum for the amount of oxygen in the Atlantic water itself, independent of the outflow from the Mediterranean; this minimum is probably a little less than the minimum for the Mediterranean water in the Alboran Sea.

In order to show more clearly the connection between the oxygen minimum and the temperature and salinity in the corresponding depth, the results of Table 11 have been marked out on Fig. 9, in such a way that the relative amount of oxygen is represented by the abscissa; the salinity is shown by the round dots, the temperature by crosses; the scales for the temperature and salinity are given to the left of the figure. It is seen, that for all the higher temperatures and salinities there corresponds a higher value for the amount of oxygen. This is due to the outflowing Mediterranean water; on the other hand, the lower temperatures and salinities, ca. 10° and 35.8 ‰, belong to the Atlantic water and a somewhat smaller amount of oxygen corresponds to these.

This water, which bears the oxygen minimum and is inclosed between the layers of water at the spot and position determined by its density, must be considered, owing to its small amount of oxygen to have been kept for a long time between the same layers. That it has sunk down from the surface in northern regions under the influence of the winter temperature seems the most probable explanation.

Under this layer the amount of oxygen increases and for the two stations 80 and 81 it even reaches 80.4 and 79.1 % respectively at a depth of 2000 m. The bottom-water has the low temperatures 3.83° and 4.20° which are characteristic for the deep water of the Atlantic.

Some details regarding the distribution of the amount of oxygen, as shown by the observations in the Atlantic and Straits of Gibraltar, may still be mentioned.

That the Mediterranean water follows the Spanish and Portugese coasts is seen from the fact, that the stations 92 and 234 have a high oxygen minimum and high temperature and salinity in comparison with the stations 91 and 232, which lie further from the coast. At St. 89, according to the observation at 700 m., the Atlantic water has pushed in towards the coast, probably in the form only of a slightly prolonged "tongue" (see fig. 3).

The distribution of the amount of oxygen in the Straits of Gibraltar in a north to south direction is shown by the figs. 7 and 8. The amount of oxygen at the bottom is to some extent constant, a little over 70 %, even if the depths are different; this is a natural consequence of the great mixing which occurs in the outflowing water when passing through the narrow Straits.

b. Balearic Sea.

For this region several sections through the stations investigated by the "Thor" are shown in figs. 10—15.

Between Cape de Gata and Oran, (106, 107, 108) June 1910 ..... fig. 10
— — — — (224, 223, 222) Sept. 1910 ..... — 11
Along the coast of Africa, (52, 51, 50, 47, 46, 45, 43) Febr. 1909 ..... — 12
From Valencia Bay to Algiers, (214, 215, 217, 218) Aug.—Sept. 1910 ..... — 13
From Barcelona to south coast of Sardinia, (210, 209, 207, 206, 204, 202) Aug. 1910 ..... — 14
From Algiers to the Gulf of Genoa, (113, 115, 116, 118, 120, 122, 123) June—July 1910 ..... — 15

Common to the stations in this region is a minimum for the amount of oxygen at a depth of 200—1000 meters with values between 66 and 76 %; from the minimum the amount of oxygen increases towards the bottom and reaches ca. 80 % at the deepest places.

In figs. 16, 17 and 18 the variation in the amount of oxygen, temperature, salinity and σ_t with the depth is shown graphically for the stations 223, 118 and 45, which may be taken as typical of the distribution of oxygen and its connection with the distribution of temperature and salinity.

It is seen, that the minimum for the amount of oxygen is almost coincident with the maximum for the temperature and salinity. The amount of oxygen rises fairly slowly towards the bottom; on the other hand, the increase is rapid from the boundary of the intermediate layer with the high temperature and salinity up towards the surface.

The low value for the oxygen at the places where it is a minimum, must certainly be due to a slow influx of oxygen here. After what J. N. Nielsen has shown in his paper in the present Report with regard to the movements of the water at these places, it is clear, that the water which holds the oxygen minimum comes from the east and has for a long time been shut off from the atmosphere; as we must believe that there is a continual consumption of oxygen in this intermediate layer, the stationary condition which is represented by the mean of the amount of oxygen at these depths, must be maintained by the introduction of new water. This also applies naturally to the bottom-water lying below this intermediate layer. The renewal of the lower layers forms presumably an analogy to the conditions in the Atlantic, but for the Western Mediterranean we are able to state with greater certainty, where the renewal comes from.

From a series of observations on the temperature and from samples taken for the determination of the salinity, which Dr. Schmidt arranged to have carried out by German and French steamers, it has proved that the surface-salinity in the Ligurian Sea and in the northern part of the Balearic Sea is so high, that the water can sink down to the bottom on cooling in winter. These conditions are discussed by J. N. Nielsen and there can be no doubt, that the bottom-layer is in this way constantly receiving such a large supply of oxygen that the stationary condition can be maintained in spite of the consumption.

With regard to the bottom-water it is remarkable how uniform the distribution of the oxygen is in the northern and southern parts of the Balearic Sea, as the renewal of

the bottom-layer can only take place in the northern part, the southern portion being always covered over by the fresher water flowing in through the Straits of Gibraltar; this shows, that there must be strong currents in the bottom-water.

To facilitate a closer study of the distribution of the oxygen at the different places in the Western Mediterranean, the stations in Table 12 have been arranged in groups, so that each group represents the part of the Western Mediterranean mentioned.

Table 12. Temperature, salinity, amount of oxygen and σ_t at stations in the Western Mediterranean, for the depth at which the lowest amount of oxygen was observed.

Region	Stat.	Depth	Temperature	Salinity	Amount of oxygen	σ_t
Central part of the eastern basin of the Balearic Sea	115	400	13.10	38.46	71.2	29.07
	116	400	13.10	38.44	71.0	29.05
	118	400	13.16	38.46	69.9	29.06
	120	250—300	13.08	38.44	71.4	29.06
Average		369	13.11	38.45	70.9	29.06
Central part of the south-western basin of the Balearic Sea and the Alboran Sea	107	400	12.99	38.39	69.0	29.04
	206	600—800	12.86	38.37	70.3	29.05
	217	950	12.84	38.36	68.4	29.04
	223	400	12.98	38.40	65.8	29.05
Average		612	12.92	38.38	68.4	29.04
Ligurian Sea	35	800	13.12	38.48	74.5	29.08
	122	200	13.54	38.55	72.2	29.04
	122	400	13.23	38.46	72.2	29.04
	123	400	13.46	38.49	73.1	29.03
	123	600	13.21	38.46	72.5	29.05
	125	600	13.15	38.42	72.2	29.03
Average		500	13.28	38.48	72.8	29.04
Catalonian and Pityusian Seas	209	600	12.76	38.37	76.0	29.06
	210	300	13.07	38.41	76.2	29.04
	210	750	12.80	38.39	75.9	29.08
	215	1000	12.76	38.35	73.8	29.05
Average		662	12.85	38.38	75.5	29.06
South-eastern part of the Balearic basin	42	1000	13.19	38.49	71.7	29.08
	43	800	13.33	38.51	72.5	29.06
	45	800	13.20	38.46	71.5	29.05
	132	1000—1200	13.21	38.46	71.0	29.04
	133	400	13.33	38.49	69.7	29.05
	134	300	13.50	38.57	67.2	29.06
	202	750	13.36	38.51	69.5	29.06
	204	400	13.28	38.50	69.6	29.06
Average		694	13.30	38.50	70.3	29.06
Southern part of the Balearic basin	46	600	12.92	38.37	71.7	29.03
	47	600	12.99	38.39	71.2	29.04
	112	300	13.00	38.36	71.6	29.01
	112	800	12.86	38.35	71.7	29.03
	113	300	13.05	38.42	69.0	29.05
	218	400	12.96	38.41	70.7	29.06
Average		500	12.96	38.38	71.0	29.04
Northern part of the Alboran Sea	54	600	12.95	38.39	75.1	29.04
	106	800	12.92	38.37	72.5	29.03
	224	500	12.98	38.40	67.2	29.05
Average		633	12.95	38.39	71.6	29.04
Southern part of the Alboran Sea	108	300	13.00	38.37	69.0	29.01

In general, however, the boundaries for these regions cannot be drawn at quite definite places, if we desire at the same time, that the stations lying within a definite region should show the characteristic distribution of temperature and salinity, which is common for the region. For example, Stations 116 and 206 lie near to one another, but have more in common with the groups in which they have been placed than with one another, in regard to the temperature and salinity at the depth where the amount of oxygen is a minimum. In a similar way Stat. 224, to judge from the minimum for the amount of oxygen, belongs rather to the same region as the central portion of the section Oran—Cape de Gata; from its situation, however, it has been included in the northern part of the Alboran Sea. The boundaries between the different kinds of water must therefore be allowed to vary somewhat with the time, but such a subdivision as that shown in Table 12 may be used in the main lines for a comparison between the different regions of the Western Mediterranean.

The first two groups of stations in Table 12, "Central part of the eastern basin of the Balearic Sea" and "Central part of the south-western basin of the Balearic Sea and the Alboran Sea", show low values for the amount of oxygen and the lowest for the region last-mentioned. It has to be remembered, however, that most of the stations in the last region were investigated later in the summer than those in the first, so that, from what we have already seen, we may for this reason expect to find a reduction in the amount of oxygen of the same order as the difference for the two regions. Nevertheless, the temperatures and salinities show that the water in the south-western part of the Balearic basin is of a different kind from that in the eastern. The water in the eastern region with its high temperature and salinity comes more directly from the layers in the Eastern Mediterranean than is the case with the water in the south-western basin.

The Ligurian Sea composes the northernmost part of the Western Mediterranean and possesses a special character, as can be seen from the mean values for the temperature, salinity and amount of oxygen, which are given in Table 12. The minimum for the amount of oxygen in the Ligurian Sea is greater than in the central part of the basin; higher temperatures and higher salinities also occur there. This suggests on the one hand a more intensive movememt of the water-layers, on the other a more rapid connection with the Eastern Mediterranean. The way from the Tyrrhenian Sea south round Sardinia and up to the Gulf of Genoa is fairly long, however, and at St. 204 we find in fact a high temperature and salinity but a low minimum for the amount of oxygen; at the Stations 118 and 120 the temperature, salinity and amount of oxygen are lower than in the Ligurian Sea and at St. 120 there is nowhere water so saline as the mean values for the Ligurian Sea; it is a question, therefore, whether the water in the Ligurian Sea is partially renewed from the Tyrrhenian Sea north round Corsica. According to an Italian chart at my disposal and after the soundings made from "Thor" the depth round Corsica is in any case more than 400 meter. For comparison of the temperatures, salinity and amount of oxygen in the Ligurian Sea with the corresponding values for the stations 33, 32, 126, 31 and 128, we have the following summary.

St. 33			St. 32			St. 126			
Depth	Temp.	Salin.	Depth	Temp.	Salin.	Depth	Temp.	Salin.	Oxyg.
100	13.33	38.13	100	13.80	37.95	100	13.93	38.10	96.2
140	13.52	38.22	150	13.55	38.12	150	13.54	38.22	88.2
			200	13.63	38.31	200	13.46	38.33	85.8
			400	13.86	38.62	300	13.51	38.51	78.1
						400	13.50	38.53	77.4

St. 31			St. 128			
Depth	Temp.	Salin.	Depth	Temp.	Salin.	Oxyg.
100	13.62	38.40	100	13.57	38.33	93.7
150	13.81	38.49	150	13.50	38.44	82.8
200	13.85	38.58	200	13.59	38.51	79.7
300	13.92	38.66	300	13.74	38.62	75.2
400	13.87	38.64	400	13.73	38.63	74.3

According to these observations we see that the northernmost stations 32 and 126 from a depth of about 300 m. contain a layer of water of sufficient warmth and salinity for the renewal of the water in the Ligurian Sea, and at the southern stations 31 and 128 we already find such a layer from a depth of 150—200 meters. We must believe therefore, that water from depths of 200—400 meters in the Tyrrhenian Sea is moving into the Ligurian Sea to form the deeper layers there. This would explain the higher amount of oxygen in that part of the Balearic Sea.

In the Catalonian and Pityusian Seas just as in the Ligurian Sea there is a larger amount of oxygen than in the central parts of the Western Mediterranean, but it is here connected with lower temperatures and salinities; we may suppose, therefore, that the movement of the water is more intensive, probably with the main direction towards the south-west, corresponding to the influence of rotation of the earth.

In the south-eastern part of the Balearic basin high temperatures and salinities are found in combination with fairly small amounts of oxygen; here we have water which flows from the Tyrrhenian Sea into the Balearic Sea. The layer with the oxygen minimum lies here as at most places elsewhere at very varying depth; at the western and northern stations it lies on the whole deeper than at the eastern stations (133, 134), as the water which comes from the south-east, bringing with it the oxygen minimum, sinks down towards the deeper parts of the Balearic Sea.

The southern part of the Balearic basin. This region has almost the same character as the central part of the south-western basin of the Balearic Sea; we may suppose that the water from the central parts is drawn in here as compensation for the east-going movement of the lighter surface-water.

The northern and southern parts of the Alboran Sea show a considerable agreement with regard to temperature and salinity; in the northern part the amount of oxygen is very variable. As can be seen from fig. 10, this part can be quite filled with water of a relatively high amount of oxygen, which probably happens during strong movements of the water. At other times the water from the central part of the Alboran Sea may extend right up to the northern part and then a small amount of oxygen occurs there (fig. 11).

To obtain a view over the distribution of the amount of oxygen in the water below the layer containing the oxygen minimum, reference may be made to Table 13, which shows the average for the

Table 13. Average values for the temperature, salinity, σ_t and amount of oxygen, at the depths 1000, 1500 and 2000 meters in the Western Mediterranean.

Region	Depth	Temp.	Salin.	σ_t	Oxygen	No. of observations used in the calculation of the average
Central part of the eastern basin of the Balearic Sea (115, 116, 118, 120)	1000	12.87	38.37	29.04	74.7	4
	1500	12.92	38.36	29.03	76.7	4
	2000	13.01	38.39	29.03	78.4	3
Central part of the south-western basin of the Balearic Sea and the Alboran Sea (107, 206, 217, 223)	1000	12.86	38.37	29.04	72.1	2
	1500	12.93	38.38	29.04	75.6	4
	2000	12.98	38.38	29.02	78.0	4
Ligurian Sea (35, 122)	1000	12.98	38.42	29.06	76.0	2
	1500	12.96	38.42	29.07	77.5	1
	2000	13.05	38.42	29.05	76.6	1
Catalonian and Pityusian Seas (209, 215)	1000	12.78	38.36	29.06	75.4	2
	1500	12.87	38.39	29.06	77.4	1
South-eastern part of the Balearic basin (42, 43, 45, 132, 204)	1000	13.11	38.44	29.05	71.9	5
	1500	13.05	38.39	29.02	73.8	3
	2000	12.99	38.35	29.00	77.5	1
Southern part of the Balearic basin (46, 47, 112)	1000	12.90	38.35	29.02	74.2	3
	1500	12.94	38.35	29.02	76.3	3
	2000	13.00	38.37	29.02	78.4	2
Northern part of the Alboran Sea (54, 106)	1000	12.91	38.37	29.03	74.4	2
Southern part of the Alboran Sea (108)	1000	12.88	38.37	29.04	73.9	1
	1500	12.93	38.35	29.02	75.8	1

amount of oxygen at the depths 1000, 1500 and 2000 meters in the same regions as before, for which the averages for the layer containing the oxygen minimum were formed. It is seen, that in 2000 m. the relative amount of oxygen is almost the same over the whole with exception of the Ligurian Sea, which has a considerably smaller amount of oxygen than is found in the other regions. At the same time the temperature and salinity are higher, in agreement with the fact, that the water which we have supposed to come from the Tyrrhenian Sea north round Corsica, sinks down to the great depths in the Ligurian Sea.

The somewhat smaller amount of oxygen at a depth of 1000 m. shows similar variations with the place to what we have found for the layer containing the oxygen minimum.

c. The Tyrrhenian Sea.

A view over the distribution of the oxygen in the Tyrrhenian Sea can be obtained from the accompanying sections through the stations.

Between the Balearic Sea and the Tyrrhenian Sea south-east of Sardinia (132, 133, 134, 135), July 1910 ... fig. 19
From the south coast of Sardinia in E.N.E. direction (42, 39, 24), Jan., Febr. 1909 ..... — 20
From the south coast of Sardinia in E.N.E. direction (202, 199, 197), Aug. 1910..... — 21
From the north coast of Corsica in S.S.E. direction (126, 128, 129, 131), July 1910 ..... — 22

On excluding the first-named section, fig. 19, from the Tyrrhenian Sea it will be seen from the other figures, 20—22, that the distribution of the relative amount of oxygen in the Tyrrhenian Sea is much more uniform in deep water than is the case in the Balearic Sea. We find here certainly a minimum in the relative amount of oxygen, but it lies much deeper and is far less marked than in the latter Sea; the amount of the increase in the oxygen from the minimum to the bottom is as a rule not more than 2 %.

The distribution of the amount of oxygen in relation to the temperature and salinity can be seen from the diagrams for the stations 24, 129 and 195 in figs. 23, 24 and 25, which may be taken as typical for the Tyrrhenian Sea.

The stations 24 and 129, like the sections figs. 20 and 21 which represent the distribution at different times, show in the main but small differences.

From the diagrams (figs. 23, 24, 25) it will be seen, that just as in the Balearic Sea there is a maximum for the temperature and salinity, but whereas in the Balearic Sea the oxygen minimum coincides with this maximum or is very little lower down, the conditions in the Tyrrhenian Sea are quite different; here the oxygen minimum lies much deeper.

As the conditions are so uniform in the whole of the Tyrrhenian Sea, we may take the average for the whole region in order to obtain a view over the distribution of the temperature, salinity and oxygen.

In Table 14 this has been done for the depths 400, 1000, 1500 and 2000 m.; 400 m. is about the depth at which the maxima for temperature and salinity occur. Of the depths mentioned, 1500 m. has the lowest value for the amount of oxygen, which might almost be seen also from the diagrams of the stations. The average for the relative amount of oxygen at a depth of 400 m. is 74.6. This is somewhat more than what was found for the minimum in the Balearic Sea, but it is on the other hand also probable, that this intermediate layer with the high temperature and salinity loses something of its oxygen on the way westwards. That this layer of water should be the bearer of the oxygen minimum in the

Table 14. Tyrrhenian Sea.

Stat.	Depth	Temp.	Salin.	σ_t	Amount of oxygen
24	400 m.	13.90	38.64	29.04	
32	„	13.86	38.62	29.03	
39	„	13.87	38.64	29.04	
126	„	13.50	38.53	29.03	77.4
128	„	13.73	38.63	29.07	74.3
129	„	13.77	38.62	29.05	75.0
194	„	13.89	38.64	29.04	74.1
195	„	13.90	38.68	29.06	73.4
197	„	13.88	38.64	29.04	73.8
199	„	13.79	38.64	29.06	74.4
Average.....	400 m	13.81	38.63	29.05	74.6
24	1000 m.	13.49	38.51	29.03	72.6
39	„	13.27	38.49	29.06	72.8
128	„	13.32	38.51	29.06	70.9
129	„	13.42	38.53	29.05	71.7
194	„	13.56	38.58	29.07	74.3
195	„	13.33	38.49	29.05	71.2
197	„	13.38	38.55	29.08	72.4
199	„	13.25	38.49	29.07	71.9
Average.....	1000 m.	13.38	38.52	29.06	72.2
24	1500 m.	13.25	38.46	29.04	72.7
39	„	13.17	38.46	29,05	72.7
128	„	13.19	38.46	29.05	70.5
129	„	13.21	38.46	29.05	71.5
195	„	13.17	38.46	29.06	69.9
Average.....	1500 m.	13.20	38.46	29.05	71.5
24	2000 m.	13.33	38.44	29.00	73.6
129	„	13.18	38.42	29.03	71.7
195	„	13.13	38.42	29.04	70.6
Average.....	2000 m.	13.21	38.43	29.02	72.0
129	2500 m.	13.20	38.40	29.00	72.0

Balearic Sea, though not so in the Tyrrhenian Sea, is certainly due to the fact, that the renewal of the bottom-water in the Balearic Sea is much more intensive than in the Tyrrhenian Sea. Nevertheless, the bottom-water in the latter may also to some extent be renewed, as is shown by the increase occurring down towards the bottom in great depths (more than 1500 m.), but its renewal must be very slow.

d. Ionian Sea and Sidra Sea.

The distribution of the amount of oxygen in the Ionian Sea and Sidra Sea is shown in the sections:

Between Cape Bon and Sicily (137, 138 and 139) July 1910 ..... fig. 26
From Straits of Messina to Gulf of Corinth (192, 189, 187, 186) Aug. 1910 ..... — 27
Over Malta in south-easterly direction (141, 142, 143, 144) July 1910 ..... — 28
Sidra Sea (145, 147, 148, 150) July 1910 ..... — 29

In the section through the stations 137, 138 and 139, fig. 26, we find 73—74 % oxygen at the depth 500—700 meters. The section from the Straits of Messina to the Gulf of Corinth, fig. 27, shows slightly higher values for the amount of oxygen at these depths and a minimum with 73.2 % at 1200 m. The intermediate maximum for the temperature and salinity lies at a depth of ca. 400 m., as can be seen from the diagrams for the stations 187 and 186, figs. 30 and 31. At the greatest depths the amount of oxygen is ca. 76 %. Stat. 192 in this section lies right in the Straits of Messina and for the same depth has considerably lower amount of oxygen than St. 189, which only lies ca. 30 miles from there; this is probably due to water passing through the Straits of Messina from the Tyrrhenian Sea into the Ionian Sea.

The section over Malta, fig. 28, lies partly in the Sidra Sea, partly in the Ionian Sea; in the western part it shows a fairly even distribution of the oxygen in deep water; on the other hand, at St. 144 we find a minimum for the oxygen of 70.2 % at a depth of 1500 m. The amount of oxygen at the bottom at this station (3200 m) is 76.1 %.

From the section through St. 144 and the stations in Sidra Bay we see, that there is a minimum of less than 69 % in the Bay at a depth of ca. 1000 m. This minimum is the most striking thing about the distribution of the oxygen in the Ionian Sea and untess we assume an extraordinarily rapid consumption of oxygen we must believe that this water has been shut off from the atmosphere for rather long time. The bottom-water in the deeper parts is fairly uniform at 75—76 %.

The diagrams for the distribution of the amount of oxygen, temperature, salinity and σ_t at the stations 143, 144, 145 and 147 are shown in figs. 32, 33, 34 and 35. It is seen that the situation of the oxygen minimum corresponds very nearly to the conditions in the Tyrrhenian Sea. The maxima for the salinity also occur here at a similar depth as in the Tyrrhenian Sea, thus in no connection with the oxygen minimum. On the other hand, the bottom-water here is a little richer in oxygen than in the Tyrrhenian Sea, which would indicate a somewhat more active renewal.

Regarding the temperature maximum it may be remarked, that this disappears at the southern stations, where the distribution of temperature in the upper layers shows a gradual rise from the lowest to the uppermost.

It is remarkable, that the relalive amount of oxygen in the surface-water is less than 100 % at most stations in the Ionian and Sidra Seas; this condition is found again in the Levant to an even greater degree. For the surface-water we have the following average values of the relative amount of oxygen.

At the stations 145 and 147	96.3 %
- — — 189 — 187	95.7 —
- — — 152	93.3 —

The distribution of the temperature, salinity, σ_t and amount of oxygen is shown below from the averages for some groups of stations.

At a depth of 300 meters, which corresponds very nearly to the situation of the maximum for the salinity, we find the temperature, salinity and amount of oxygen somewhat greater than in the Tyrrhenian Sea at a depth of 400 m., which corresponds very closely to the situation of the maximum temperature and salinity in the latter.

The difference between the two seas is approximately as follows:

temp.	salin.	σ_t	oxygen
0.17	0.10	0.04	3.9 %

Table 15.

Stations	Depth	Temp.	Salin.	σ_t	Oxygen
138, 139, 192, 189, 187, 186, 141, 143, 144, 145, 147, 152.	300 m.	13.98	38.73	29.09	78.5
189, 187, 186	1000 -	13.57	38.69	29.15	73.7
143		13.56	38.65	29.12	73.7
144, 145		13.58	38.67	29.12	69.8
152		13.50	38.66	29.14	71.9
186	1500 -	13.57	38.68	29.13	72.0
143		13.56	38.64	29.11	74.2
144, 145		13.54	38.64	29.11	70.6
152		13.50	38.64	29.12	72.5
144	2000 -	13.56	38.64	29.11	72.9
152		13.52	38.64	29.11	74.2
144	2500 -	13.60	38.64	29.10	74.2

The relatively low temperature, salinity and amount of oxygen at the Stations 138 and 139 are probably due to an exchange of water between the Ionian and Tyrrhenian Seas.

At a depth of 1000 m. the distribution of the temperature and salinity is fairly uniform; at the stations 144 and 145 the amount of oxygen shows the already mentioned minimum. The conditions at 1500 m. are somewhat similar. At the deepest stations, 2000 m. and more, the conditions are uniform, the amount of oxygen increasing towards the bottom with values between 72 % and 76 %. This is not in agreement with what was earlier found in this region by the Pola Expedition (Natterer, 1892, p. 93 and 94).

At the stations 64, 65 and 66 of the Pola Expedition, lying in the middle of the Ionian Sea, the

following amounts of oxygen were found, for example, at the depths 3550, 3580 and 3700 m., respectively 79.8, 67.9 and 44.1 %. These results show so much irregularity in the distribution of the oxygen by comparison with the "Thor's" observations, that we can scarcely attach great weight to them, the number of observations being very small. In the case of the other determinations of the amount of oxygen made by the Pola Expedition in the Ionian Sea at lesser depths, there is however a similar distribution of the amount of oxygen to that found on the Thor Expedition.

With regard to the renewal of the bottom-water, we have seen, that this probably takes place with some rapidity in the Balearic basin, but more slowly in the Tyrrhenian Sea; to judge from the amount of oxygen in the bottom-water compared with the minimum value in the intermediate layers from 1000—1200 m., we may conclude that the Ionian Sea and Sidra Sea take up an intermediate position in this regard. To throw light on the way in which the bottom-water in this region is renewed, we may make use of the Austrian and Italian hydrographical investigations in the Adriatic, regarding which Prof. Brücker (1911, p. 193) and Prof. Grund (1911, p. 262) have published preliminary notices. During the period when the investigations were carried out (25. Febr.— 7. March 1911) the water was almost everywhere completely homothermal and homohaline in a vertical direction. The observations on the amount of oxygen showed, that the water, except at a few deep spots, was saturated with oxygen. For the sake of comparison we may take the results of the "Thor's" observations in the Straits of Otranto (St. 15) in the winter of 1909.

Depth	Amount of oxygen
600 m.	87.8 %
800 -	79.4 -
950 -	87.7 -

As these values for the amount of oxygen are greater than those found elsewhere in the same depths, it seems by no means improbable, that water may come from these parts to sink down into the depths of the Ionian Sea. In connection with this it may be mentioned, that a high percentage of oxygen (ca. 87 %) was found in the deep water at St. 184 in the Gulf of Corinth along with a low temperature ca. 12.8°; it looks as if the cooling process in winter is stronger in the neighbourhood of the land and produces more intensive convection-currents.

e. The Levant.

The distribution of the amount of oxygen in the deeper layers of the Levant can be seen from a section through the stations 154, 156, 158 and 160 (fig. 36). In the main features we have here again the conditions found in the western regions; a decrease in the amount of oxygen with the depth to a minimum, reached here at a depth of ca. 1700 m., the minimum value being ca. 67 % and the amount of oxygen ca. 70 % at the greatest depths, ca. 3000 m. Figs. 37 and 38 give diagrams for the variation of the temperature, salinity, σ_t and amount of oxygen with the depth at the stations 156 and 160.

At the time when the observations were made (July—August 1910) the oxygen in the surface-water of the Levant shows the peculiarity, that its relative amount is considerably less than 100 %; this was also the case in the Ionian Sea, especially at St. 152.

Table 16 shows, that the relative amount of oxygen in the surface-water has a mean value of 93.3 % and the same value was found in the surface-water at St. 152. Such a low value for the amount of oxygen in the surface-water is somewhat unusual; it is probably due to the fact, that the water at the surface has at times been greatly heated, so much so that the absolute amount has been reduced and that no oxygen, after cooling has set in, has been taken from the atmosphere. It is seen from the thin

surface-layer of less than 25 m., that this has been greatly heated, leading to an increase of the salinity by evaporation. If water with such a temperature and salinity as that found were just saturated with oxygen, a cooling of ca. 4° would produce the undersaturation observed, unless oxygen were taken at the same time from the atmosphere. That a great heating of the water, with succeeding cooling may have occurred a short time before the observations were made, is in fact not improbable, as these were taken late in July. It has to be remembered, however, that undersaturation produced in this manner cannot last very long; in the course of ca. 4 days I have found it in Danish waters to be reduced by the half through contact with the atmosphere (1908, p. 17). Possibly the main reason for the undersaturation observed is, that the determinations were made in the evening and morning and it may be supposed, that the variation in the amount of oxygen at the surface in the course of 24 hours is considerably greater in this region than in the northern part of the Mediterranean, for which we found a difference of 1.8 % between the day and night.

Table 16.

Stat.	Depth	Temp.	Salin.	σ_t	Amount of oxygen
154	0 m.	24.60	38.68	26.27	92.0
156	„	25.47	39.04	26.26	94.6
158	„	24.08	39.18	26.80	93.2
160	„	26.28	39.22	26.15	93.4
Average.....	0 m.	25.11	39.03	26.37	93.3
154	200 m.	15.29	38.89	28.92	81.9
156	„	15.11	38.91	28.98	85.8
158	„	14.59	38.89	29.08	82.2
160	„	14.36	38.86	29.11	78.1
Average.....	200 m.	14.84	38.89	29.02	82.0
156	1000 m.	13.64	38.68	29.12	68.4
158	„	13.61	38.64	29.10	67.5
160	„	13.60	38.68	29.13	67.9
Average.....	1000 m.	13.62	38.67	29.12	67.9
156	2000 m.	13.62	38.64	29.09	67.5
158	„	13.63	38.63	29.09	66.7
160	„	13.61	38.68	29.13	67.4
Average.....	2000 m.	13.62	38.65	29.10	67.2
156	2975 m.	13.76	38.66	29.08	70.5
160	3000 m.	13.78	38.66	29.08	71.0
Average.....	2987 m.	13,77	38.66	29.08	70.7

Under the surface, at a depth of 25 to 75 m. we find, that supersaturation occurs in a similar way to what we found in the western parts of the Mediterranean, but not to the same extent.

The temperature and salinity maxima, which were so characteristic in the western parts of the Mediterranean, are absent here in most cases, the transition from the temperature and salinity of the intermediate layer to those of the surface showing a steady increase. At St. 156, however, a well-marked salinity maximum lies at a depth of ca. 200 m., thus nearer the surface than the maximum in the Ionian Sea. The temperature, salinity and amount of oxygen are also higher at this depth than at 300 m. in the Ionian Sea (cf. Table 16).

In the deepest parts of the Levant the salinity is practically the same as in the Ionian Sea, e. g. at 1000 and 2000 m.; the temperature on the other hand is a little higher in the Levant by ca. 0.1°, but the greatest difference is seen in the amount of oxygen, about 5 %. This indicates that the renewal of the bottom-water in the Levant proceeds slowly and is of the same nature as in the Tyrrhenian Sea.

f. Aegean Sea.

Observations were made at 4 stations in this region, 163, 181, 182 and 183.

The distribution of the temperature, salinity, σ_t and amount of oxygen at the two stations 163 and 182 is represented graphically in figs. 39 and 40. It is seen that the distribution of the salinity at St. 163 is very uniform in the uppermost layers; apart from a small rise of only 0.03 ‰ at 75 m. there is also an even decrease in the salinity with the depth. The possibility is thus present for the existence of strong convection-currents during the cooling process in winter. This also agrees with the fact, that the amount of oxygen, like the temperature and salinity, is higher in deep water than is elsewhere the case in corresponding depths in the western part of the Mediterranean.

To illustrate this condition a summary is given below of the temperature, salinity, σ_t and amount of oxygen at a depth of 1000 m. in the different regions.

	Temp.	Salin.	σ_t	Oxygen.
Balearic Sea	12.91	38.38	29.04	74.1
Tyrrhenian Sea.....	13.38	38.52	29.06	72.2
Ionian and Sidra Seas..	13.55	38.67	29.13	72.3
The Levant	13.62	38.67	29.12	67.9
Aegean Sea (St. 163)....	13.36	38.84	29.30	89.5

There can be no doubt, therefore, that the renewal of the water in the deeper layers proceeds here much more rapidly than in the western parts of the Mediterranean.

As is usually the case we find a supersaturation in the depths 25—50 m., but it is only slight here.

To judge from the variation of σ_t, the state of equilibrium is quite stable in the summer time, and we may suppose therefore that no new addition has been made to the amount of oxygen during the summer. The consumption of oxygen at this place in the course of half a year may thus be estimated at ca. 10 %, as the amount of oxygen at the bottom is found to be 88.4 %.

Whilst the surface-salinity at St. 163 is 39.13, it is only 38.03, 36.64 and 38.13 at the stations 181, 182 and 183 respectively, thus very variable, probably owing to the influence of the water flowing out from the Sea of Marmora. At St. 182, however, the amount of oxygen has similar values as at St. 163.

On the other hand, at St. 183 which only has a depth of 225 m. and is situated in the Gulf of Athens, the amount of oxygen at the bottom is lower, ca. 77 %, and the temperature is also low ca. 12.7°, which suggests similar conditions to those in the Gulf of Corinth.

g. Sea of Marmora.

In the Sea of Marmora 4 stations were investigated hydrographically 177, 175, 174 and 170, but determinations of the amount of oxygen were not made for the station 174.

Figs. 41 and 42 show the distribution of the temperature, salinity, σ_t and amount of oxygen according to the depth at the stations 170 and 175. In deep water from ca. 50 m. down to the bottom, the salinity is greater than 38.40 at all stations. At St. 177 near the narrows of the Dardanelles it is even 38.77 at a depth of 50 m.; on the other hand, the salinity at the surface is only ca. 22 %. There can be no doubt, that the salt bottom-water from the Aegean Sea penetrates into the Sea of Marmora through the Dardenelles and sinks to the bottom there, whilst, as compensation, water from the Black Sea is spread over the Sea of Marmora in the surface layers. Since, therefore, the salt water lying below is always shut off from the atmosphere, its amount of oxygen becomes reduced by consumption; the great decrease begins at ca. 50 m. in the uppermost part of the salt water and the amount of oxygen sinks to a minimum, which at stations 170 and 175 amounts to 27.3 and 31.9 % respectively and at both stations lies at a depth of 300 m.

As the amount of oxygen at the bottom is ca. 10 % greater than the minimum at 300 m., it is probable, that the renewal brought about by the inflowing saltwater begins at the bottom, as the inflow owing to its greater density sinks down to the bottom and only mixes gradually with the upper layers.

In the surface-water itself the amount of oxygen is a little under 100 %, as is usually the case especially in the eastern part of the Mediterranean; at a depth of 20 m., at stations 177 and 170, the supersaturation amounts to respectively 110.4 and 107.7, which must certainly be ascribed to the development of oxygen by organisms; as has been known from elsewhere, these occur at the depth where the gradient of density is greatest (Jacobsen, 1908, p. 23).

h. Black Sea.

In the Black Sea there is a single station 172, with a depth of 1000 m., at which the amount of oxygen was determined. Whilst the distribution of the oxygen in the upper layers is essentially the same as in the Sea of Marmora with a slight undersaturation at the surface and a considerable supersaturation at a depth of 20—25 m. (113.5—111.6 %), greatest interest at this station is attached to the fact, that the amount of oxygen not only decreases to 0, but that hydrogen sulphide is found even at 200 m. and from there to the bottom; in the Tables p. 65 this is indicated with a negative sign.

The renewal of the bottom-water must therefore proceed much more slowly than in the regions previously discussed.

To judge from the observations of the "Thor", the depth at which hydrogen sulphide is first met with lies between 150 and 200 m. and this agrees well with the result arrived at by LEBEDINTSEF from a careful investigation at several stations (LEBEDINTSEF 1893 p. 420).

V. Summary.

The present paper is based on ca. 1200 determinations of the amount of oxygen at stations in the Mediterranean and adjacent waters; it discusses the variation in the amount of oxygen with the time and place.

There is a variation in the course of 24 hours in the surface-water and uppermost layers, both in regard to the absolute and the relative amount of oxygen.

Further, a variation has been shown in the different depths with the season of the year.

The vertical distribution of the relative amount of oxygen shows as a rule saturation in the surface-water, whilst supersaturation is found as a rule at a comparatively slight depth, according to the available observations from June to September. Deeper down, in varying depths there is an intermediate minimum for the amount of oxygen everywhere except in the easternmost part of the Mediterranean.

The distribution of the amount of oxygen characteristic for the separate regions is discussed in the various sections.

Whilst the above-mentioned intermediate minimum is most marked in the Western Mediterranean, at certain places in the Eastern we find such large relative amounts of oxygen in deep water (St. 163), that we must conclude, that convection-currents extending down to the deepest layers may occur in the winter-time.

The water which flows westwards from the eastern part of the Mediterranean, forms an intermediate layer, which in its progress, being always excluded from the atmosphere, gradually becomes the bearer of the oxygen minimum.

Renewal of the bottom-water, by which its amount of oxygen becomes relatively high, takes place by means of convection-currents in the winter at certain places, for example, in the Ligurian Sea.

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* Mentioned by Lütgens in the Ann. d. Hydrographie 1911, p. 447.

STATIONS AND SECTIONS.

● Station-diagrams shown in the plates. Sections shown in the plates.

The fat numbers represent the numbers of the diagrams and sections in the plates.

Fig. 1. Stat. 80.
13. June 1910.

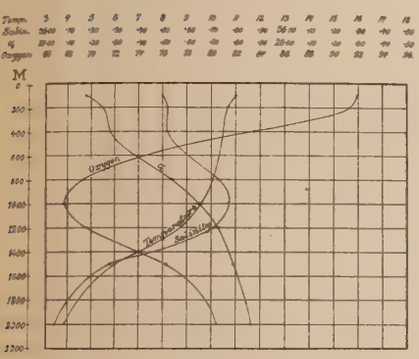


Fig. 2. Stat. 87.
17. June 1910.

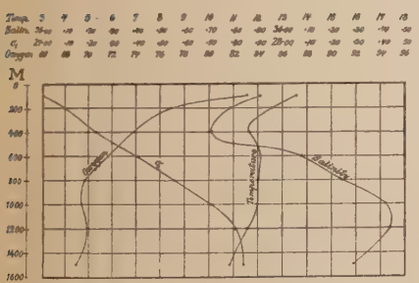


Fig. 3. S.W. coast of Spain.
June 1910.

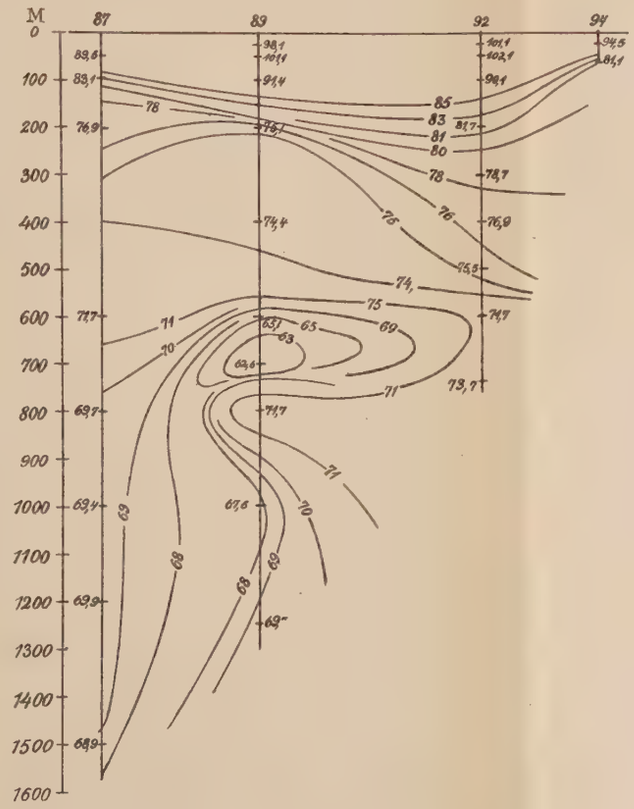


Fig. 4. Straits of Gibraltar, E. to W.
Febr. 1909.

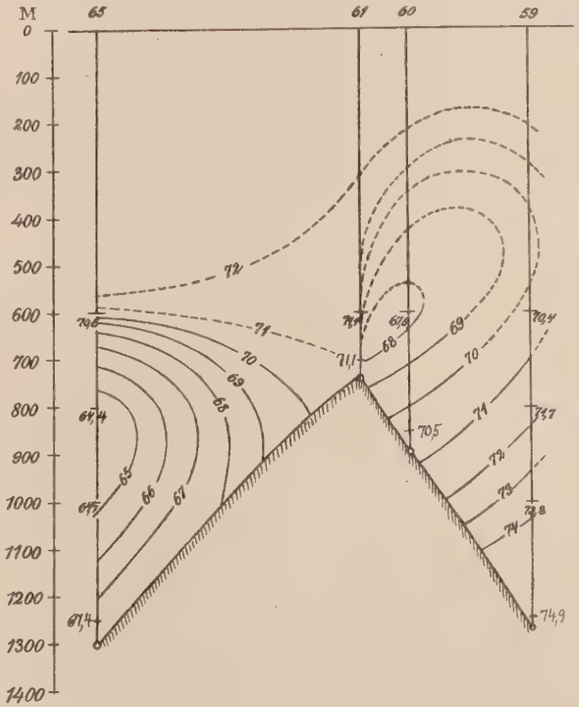


Fig. 5. Straits of Gibraltar, E. to W
June 1910.

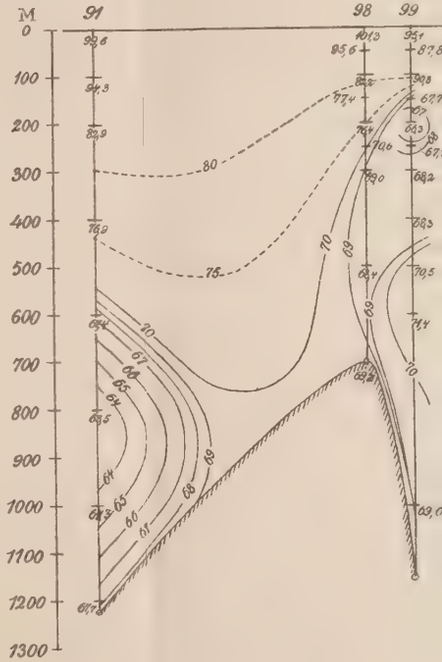


Fig. 7. Straits of Gibraltar,
N. to S. June 1910.

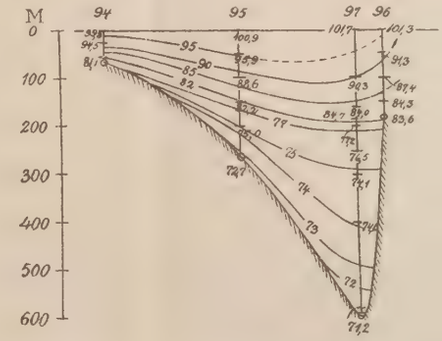


Fig. 9.

× Temperatures from 5/8 Thor.
• Salinities — —
+ Temperatures from 8/8 Planet.
○ Salinities — —

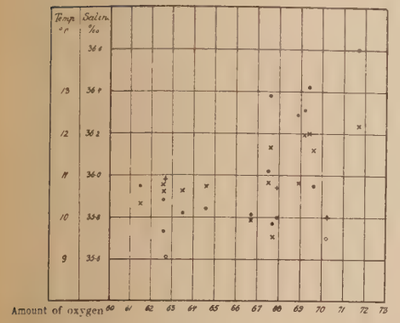


Fig. 10. Cape de Gata to Oran.
June 1910.

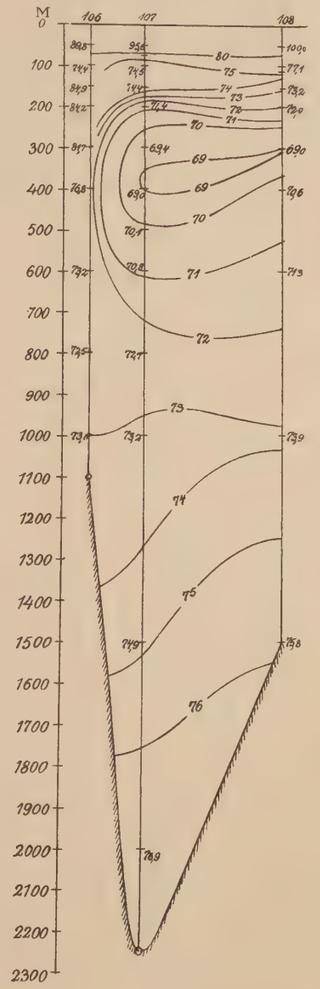


Fig. 11. Cape de Gata to Oran.
Sept. 1910.

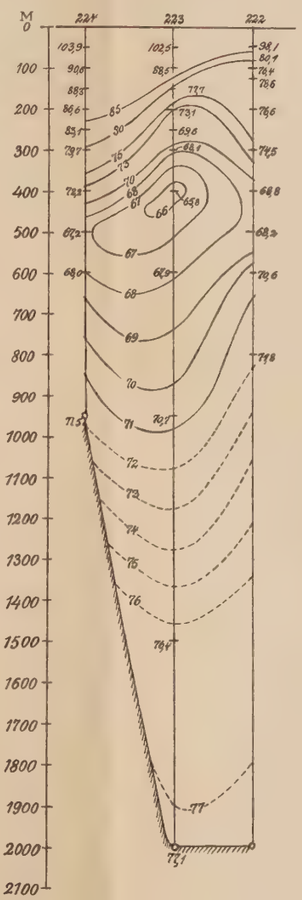


Fig. 12 Along coast of Africa.
Febr. 1909.

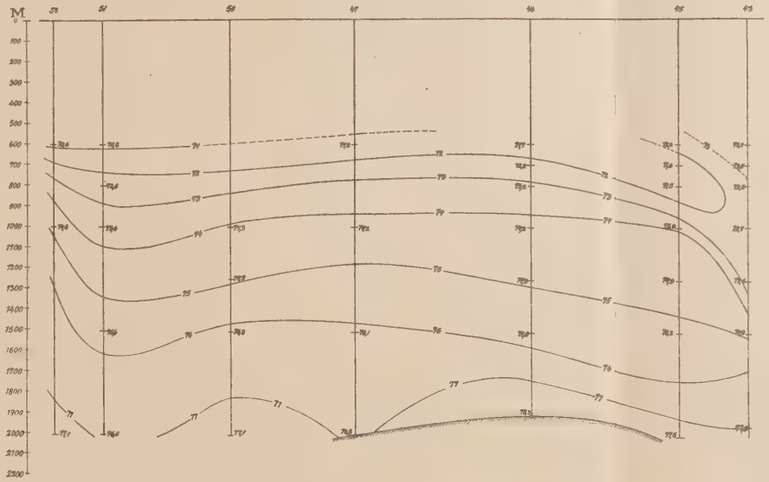


Fig. 13. Valencia Bay to Algiers.
Aug.—Sept. 1910.

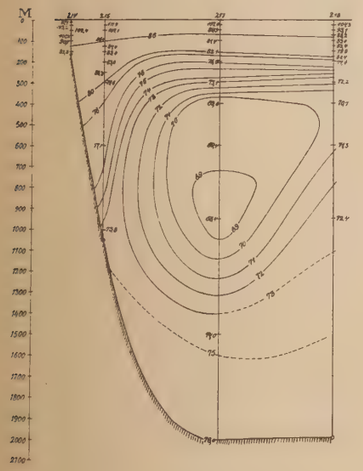


Fig. 14. Barcelona to south coast of Sardinia.
Aug. 1910.

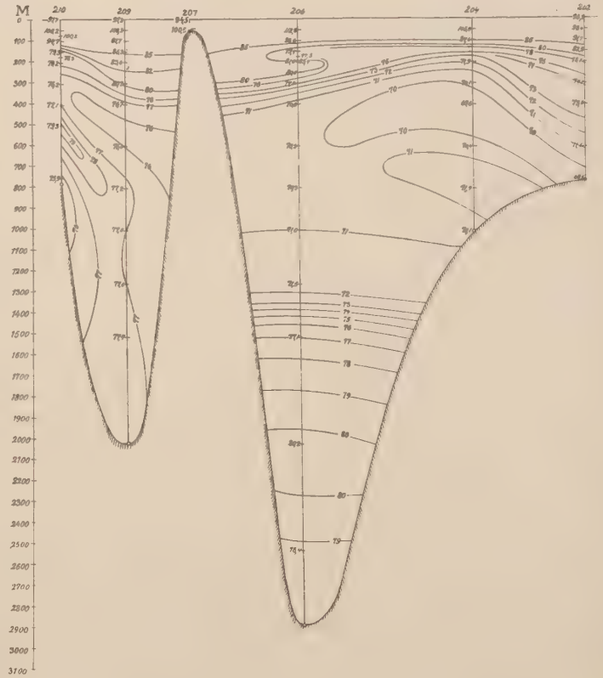


Fig. 15. Algiers to Gulf of Genoa.
June—July 1910.

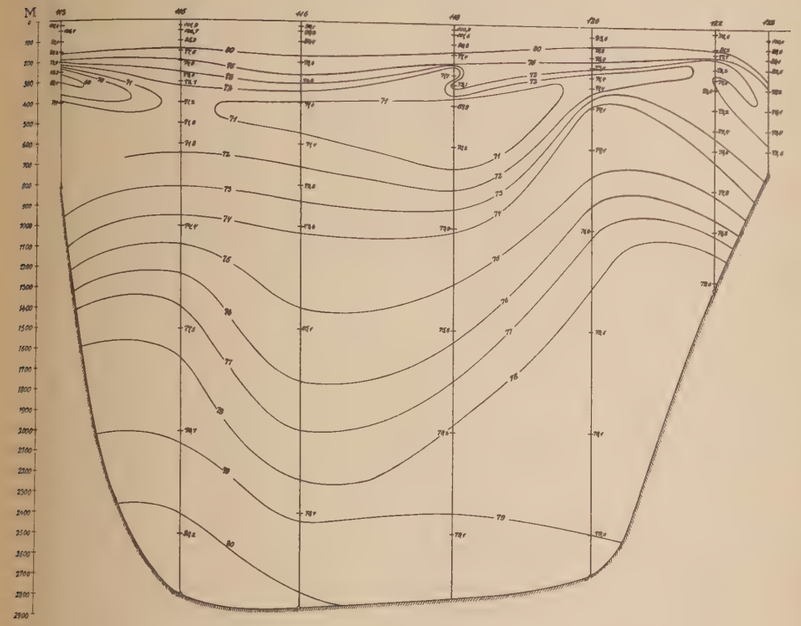


Fig. 16. Stat. 223. 5. Sept. 1910.

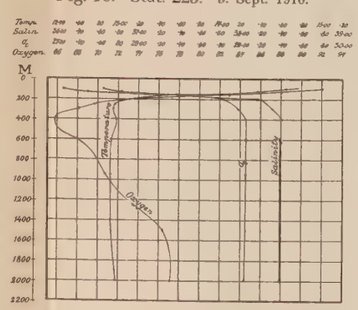


Fig. 17. Stat. 118. 30. June 1910.

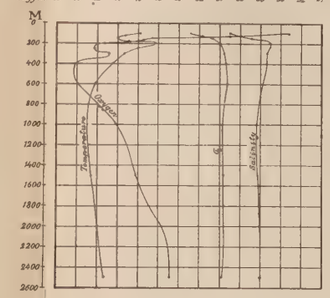


Fig. 18. Stat. 45. 6. Febr. 1909.

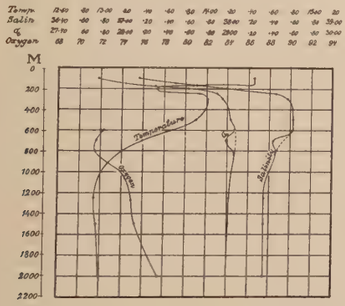


Fig. 19. S.E. of Sardinia.
July 1910.

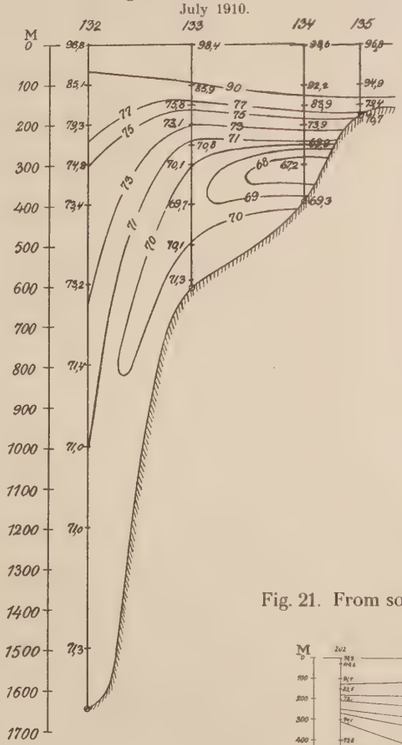


Fig. 20. From south coast of Sardinia to the E.N.E.
Jan.—Febr. 1909.

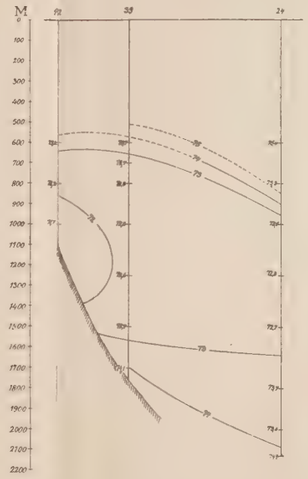


Fig. 21. From south coast of Sardinia to the E.N.E.
Aug. 1910.

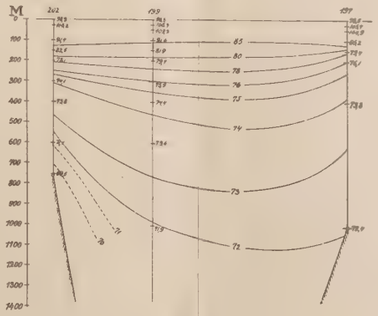


Fig. 22. From north coast of Corsica to the S.S.E.
July 1910.

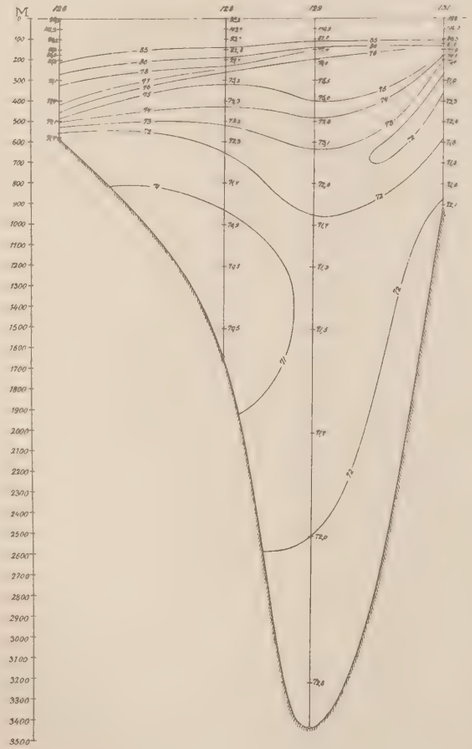


Fig. 23. Stat. 24. 16. Jan. 1909.

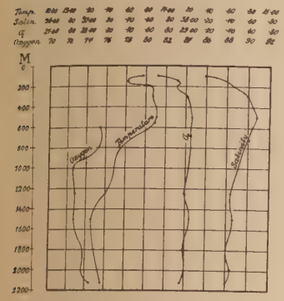


Fig. 24. Stat. 129. 12. July 1910.

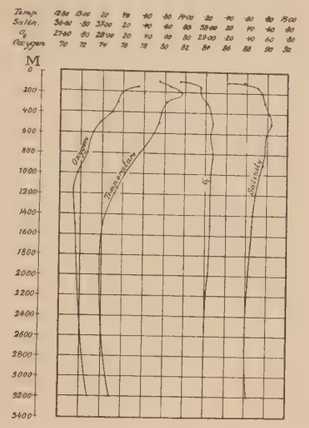


Fig. 25. Stat. 195. 21. Aug. 1910.

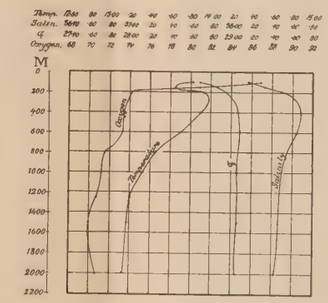


Fig. 26. From Cape Bon to Sicily.
July 1910.

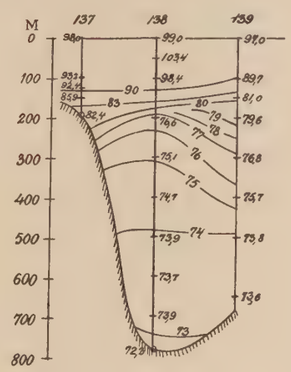


Fig. 27.
From Straits of Messina to Gulf of Corinth.
Aug. 1910.

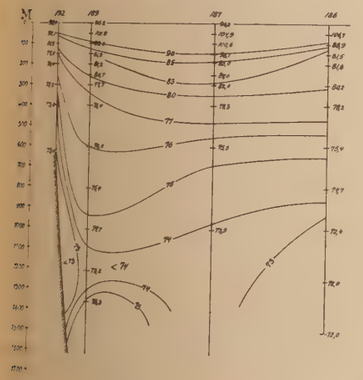


Fig. 28. Over Malta in south-east direction.
July 1910.

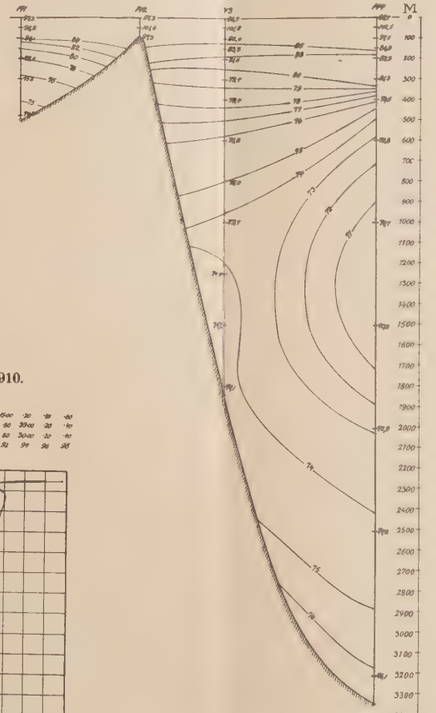


Fig. 29. Sidra Sea.
July 1910.

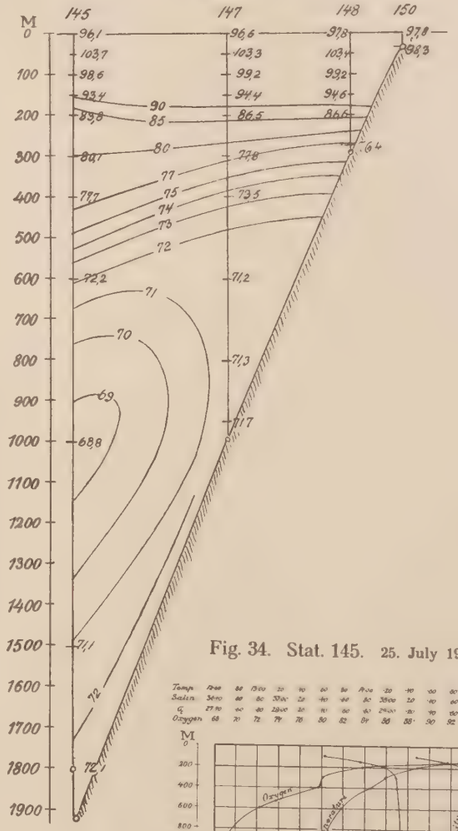


Fig. 30. Stat. 187. 18. Aug. 1910.

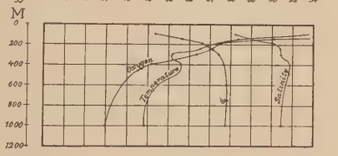


Fig. 31. Stat. 186. 17. Aug. 1910.

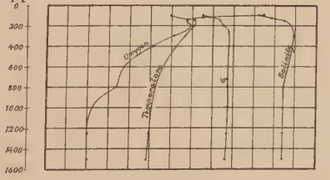


Fig. 32. Stat. 143. 22. July 1910.

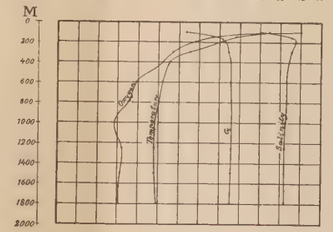


Fig. 33. Stat. 144. 23. July 1910.

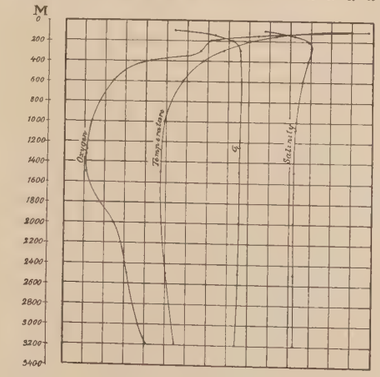


Fig. 34. Stat. 145. 25. July 1910.

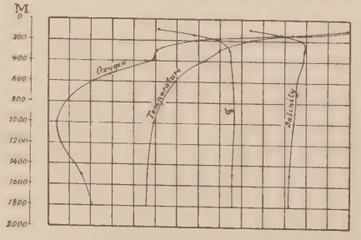


Fig. 35. Stat. 147. 25. July 1910.

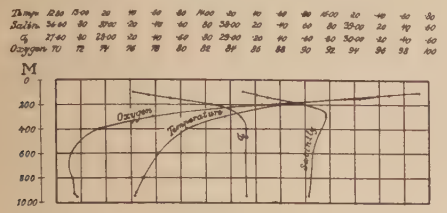


Fig. 36. The Levant.
July—Aug. 1910.

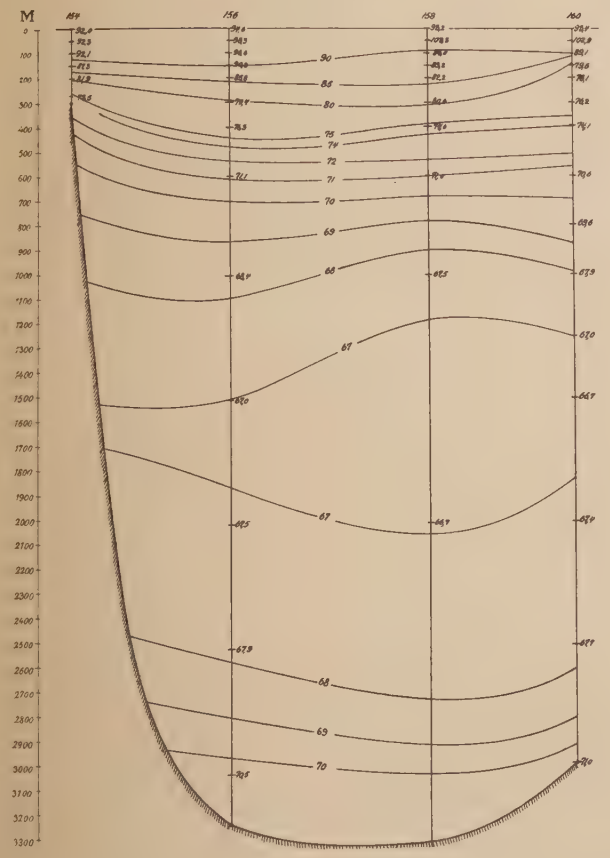


Fig. 37. Stat. 156. 29. July 1910.

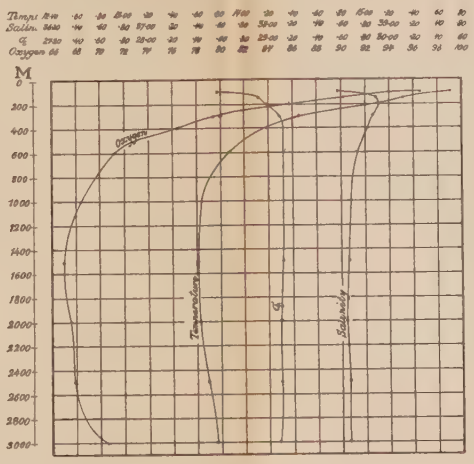


Fig. 38. Stat. 160. 1. Aug. 1910.

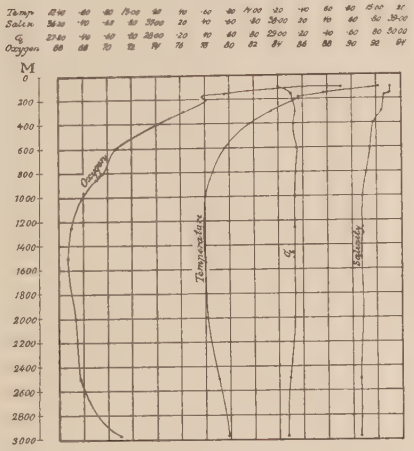


Fig. 39. Stat. 163. 2. Aug. 1910.

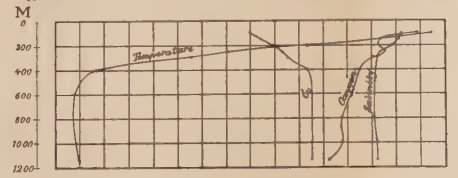


Fig. 40. Stat. 182. 13. Aug, 1910.

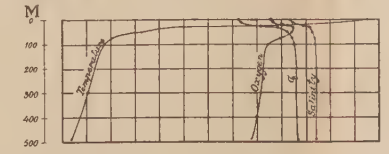


Fig. 41. Stat. 170. 6. Aug. 1910.

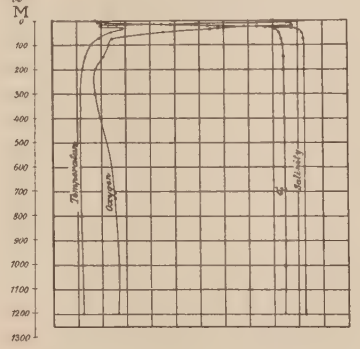
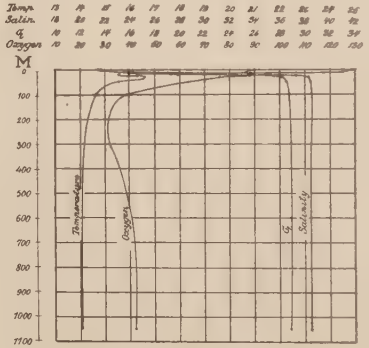


Fig. 42. Stat. 175. 11. Aug. 1910.



6.

Measurement of the Hydrogen Ion Concentration in Seawater

by

Sven Palitzsch

CONTENTS

page

I. Historical Introduction 239
II. Theoretical Remarks 240
III. The Colorimetric Method of Measurement 242
IV. Practical Application of the Method 245
V. The values of the Hydrogen Ion Concentration in Seawater found on the Expedition 247
VI. Summary 251

I. Historical Introduction.

The earlier hydrographers, v. Bibra, [1851 p. 90], Guignet and Telles [1876 p. 920] and Tornoe [1880 p. 27] found in a purely qualitative way that seawater shows a distinct though feeble alkaline reaction.

At a time when it was not yet understood, how the carbonic acid occurred in seawater, Tornøe [1880] worked out a method by means of which the quantity of "neutral" and of "acid", bound carbonic acid could be determined. The number of cc. neutral bound carbonic acid in a litre — an amount for which Dittmar [1884] later introduced the name alkalinity — was determined by adding hydrochloric acid to the seawater, boiling off the free carbonic acid and titrating the excess of acid with sodium hydrate or iodometrically by means of thiosulphate. This however does not give the amount of chemically bound carbonic acid, as the latter occurs partly as normal partly as acid carbonate, but the amount of the bases combined with the carbonic acid. On comparing this quantity of bases with the total quantity of carbonic acid, it will be found in most samples of seawater that there is far from being sufficient carbonic acid to form bi-carbonates with these bases; consequently, a quantity of monocarbonate must also be present and as the monocarbonates of calcium or sodium in aqueous solution give a strongly alkaline reaction, we can conclude from the analyses, that the seawater has perhaps an alkaline reaction, but from these we by no means obtain any certain, not to mention quantitative, determination. A rational expression for the acidity or alkalinity of seawater can only be obtained by measuring the hydrogen ion concentration, as will be described in the sequel.

Natterer [1892 p. 83, 1893 p. 54] has observed that water from the eastern parts of the Mediterranean is coloured red by phenolphtalein and on comparing the different shades of red, he found, that the bottom-water is less alkaline than the surface-water. Ruppin [1909 p. 281] is of opinion, on the other hand, that seawater is not coloured by phenolphtalein. This observation is possibly due to the fact, that only seawater from the North Sea and Baltic in the neighbourhood of Kiel was examined. According to J. Loeb's investigations [1907 p. 186] water from Woods Hole on the Atlantic coast was coloured red by phenolphtalein. Water from the San Francisco Bay [Loeb 1903 p. 637] and from Pacific Grove on the Pacific, as also the water from the Naples aquaria examined by Bethe [1909, p. 256] was, on the other hand, too acid to be coloured by phenolphtalein, but coloured orange with neutral-red; from these results Loeb and Bethe estimate the hydrogen ion concentration to be 10^{-8} (i. e. that there is 1/100000000 gm.-equivalent of hydrogen as ions in each litre of seawater).

Ringer [1908], who was the first to measure the reaction of seawater quantitatively, found from a large series of electrometric determinations on seawater from the North Sea, Zuidersee and Bømmel Fjord, that the water investigated was feebly alkaline; the hydrogen ion concentration was found to be between 0.58×10^{-8} and 1.40×10^{-8} (see later).

The vital importance of the hydrogen ion concentration for the physiological processes occurring in seawater, has been very distinctly shown by the large number of experiments made by LOEB on the development of the eggs of various marine animals. To mention one characteristic example; he found that the parthenogenetic development of the eggs of Strongylocentrotus only succeeded very imperfectly in the comparatively acid water of Pacific Grove (see above), whereas the water of Wood's Hole always gave an abundance of larvae. An addition of a small quantity of dilute sodium hydrate to the water of Pacific Grove also made this well-suited for the development of the eggs.

The importance of the hydrogen ion concentration has also been proved for quite different biological phenomena in the sea. Thus, BETHE [1909 p. 219] has found, in regard to the rhythmic movements of the Medusae, that when the hydrogen ion concentration is increased from 10^{-8} to 10^{-7} or 10^{-6}, the movements are hastened, whilst a concentration of 10^{-5} or 10^{-9} will diminish or paralyse the movements.

II. Theoretical Remarks.

Even the purest water is a conductor of electricity, though only to a small extent. It is assumed, therefore, that an inconsiderable portion of the water-molecules are dissociated, that is, split up into two electrically laden parts (ions), namely, the positively laden hydrogen ion (H' or H^+), and the negatively laden hydroxyl ion (OH' or OH^-).

According to GULDBERG and WAAGE's law of mass action the product of the hydrogen ion concentration (H') and the hydroxyl ion concentration (OH') in any aqueous solution, divided by the concentration of the undissociated water-molecules, should be constant. In dilute solutions where the water largely predominates we may consider its concentration as constant and thus have

$$[H'] \, [OH'] = \text{a constant.}$$

This constant, which is usually called the ionization constant of the water, has been found to be about 10^{-14} by means of a number of very different methods which have given somewhat similar results. The average of a large series of measurements, which have been carried out at the Carlsberg Laboratory, has given the value $10^{-14.14}$, and this has been used in the sequel. It is readily seen that, when the constant is known, the above equation enables the hydroxyl ion concentration to be calculated, when the hydrogen ion concentration has been determined experimentally, and conversely. For accurate measurements the temperature must be known, as the constant varies greatly with this; the value $10^{-14.14}$ holds good for the temperature 18° C.

As pure water as well as all really neutral aquous solutions contains just as many hydrogen as hydroxyl ions, both $[H']$ and $[OH']$ will in this case be $10^{-7.07}$ as

$$10^{-7.07} \times 10^{-7.07} = 10^{-14.14}$$

Expressed in another way this means that in a litre of perfectly pure water at 18° C. there will be $10^{-7.07}$ gm.-molecules of water dissociated into hydrogen ions and hydroxyl ions.

If an acid is added to the water, it will be dissociated into positive hydrogen ions and negative acid ions. The equation then shows, that to obtain equilibrium water must be formed from the hydrogen and hydroxyl ions, until the product of the concentration of hydrogen and hydroxyl ions is again $10^{-14.14}$.

If a base, e. g. sodium hydrate, is added to the water, the quantity of hydroxyl ions will in the same way be increased and the number of hydrogen ions correspondingly reduced. Even in the case of such alkaline solutions, however, it is most usually the hydrogen ion concentration that is taken account of, as this can be determined with greatest accuracy.

The different acids and bases increase or diminish the hydrogen ion concentration to a very unequal extent. Those which change the concentration most are called the strongest. That which characterizes a substance as acid is just its power to increase the hydrogen ion concentration, whilst a base on the other hand diminishes it or, what is the same thing, increases the hydroxyl ion concentration. In all the reactions of acids and bases which have been measured quantitatively, it has constantly been found that the action is almost exclusively dependent on the quantity of hydrogen ions or hydroxyl ions and only to a small extent on the other ions or undissociated molecules.

If an acid solution, containing therefore many hydrogen ions, is mixed with an alkaline solution, which contains many hydroxyl ions, water must be formed from the hydrogen and hydroxyl ions, in order that the concentration product may remain at $10^{-14.14}$,

$$\text{for example, } \underset{\text{hydrochloric}}{H^{\cdot} + Cl'} + \underset{\substack{\text{sodium}\\ \text{hydrate}}}{Na^{\cdot} + OH'} = \underset{\text{salt}}{Na^{\cdot} + Cl'} - \underset{\text{water}}{HOH}$$

By the formation of salt the oppositely laden atoms are neutralized. A solution is neutral, when it contains just as many hydrogen as hydroxyl ions. Even if we mix equivalent quantities of acid and base, it is yet only in very few cases that we obtain a neutral solution, namely, only when the acid and base are dissociated to an exactly equal extent. An aqueous solution of a salt of a weak acid and a strong base, e. g. sodium borate, will on the other hand have fewer hydrogen ions than pure water, it will be alkaline; the salt will hydrolyse, that is, alter its constitution with the water;

$$NaH_2BO_3 + H_2O = NaOH + H_3BO_3,$$

so that sodium hydrate and boric acid are formed. As the sodium hydrate is completely dissociated practically into hydroxyl ions and sodium ions whilst the weak boric acid is only able to form few hydrogen ions, there will be more hydroxyl than hydrogen ions and thus the liquid will be alkaline. In the same way a salt of a weak base and a strong acid will give an acid solution.

If a strong acid is added to such a hydrolysed salt, e. g. hydrochloric to sodium borate, the chlorine ions of the acid will form sodium chloride with the sodium ions and a portion of the hydrogen ions of the acid will unite with hydroxyl ions and form water. As soon as the sodium hydrate is "removed" in this way, more borate will be split up into boric acid and sodium hydrate, which again neutralizes some hydrochloric acid and so on. Thus, if a hydrolysed salt is present in the solution, an addition of acid will increase the hydrogen ion concentration much less than if the acid were added to pure water or to a solution of sodium chloride, which is not at all hydrolysed. In S. P. L. Sørensen's "Etudes enzymatiques" II [1909 p. 18; 1909 a, p. 149] the borate is said to act as "buffer", as small quantities of acid or base do not appreciably alter the hydrogen ion concentration.

Other weak acids behave like boric acid, for example, carbonic acid; as is well known the normal carbonates give strongly alkaline, aqueous solutions.

It is known that the principal physiological and biological processes are to a great extent dependent on the quantity present of acids and bases. As the above has shown, we might easily come to misleading results by merely measuring the quantity of acid added, for the hydrogen ion concentration, which is certainly the main factor, is dependent not only on the quantity of acid but also and essentially on the quantity and dissociated condition of all the other substances present. This applies especially to liquids having the hydrogen ion concentration in the neighbourhood of the neutral point, a region which is of the greatest importance for physiological and hydrological investigations.

Of the acids in seawater the carbonic acid, with its characteristic and complicated conditions of dissociation, is the one which has the greatest importance for the hydrogen ion concentration. Hamberg [1885 p. 31] already introduced the law of mass action into hydrography, and Fox [1909] and later Ruppin

[1909 p. 279] use the theory of ions to account for the many different forms in which the carbonic acid occurs in seawater.

The ordinary gaseous carbonic acid is, as known, a combination of oxygen and carbon: CO_2. Dissolved in water it combines with this to form a dibasic acid; $H_2CO_3 (= CO_2 + H_2O)$, which will be dissociated into hydrogen ions and HCO'_3, so that $[H'] [HCO'_3] = 3 \times 10^{-7} [H_2CO_3]$. The ion HCO'_3 will also be dissociated, namely into H' and CO''_3, but the dissociation constant for this process is 5000 times less ($[H'] [CO''_3] = 6 \times 10^{-11} [HCO'_3]$; Auerbach and Pick 1911 p. 265) than for the dissociation of the first hydrogen atom; only an appreciably small part of H_2CO_3 will therefore be completely dissociated, and from what has been explained above (p. 5) it will be clearly seen, that a solution of normal sodium carbonate must have a great excess of hydroxyl ions.

A portion of the carbonic acid in the water will occur as absorbed gas, like every other kind of gas, and as such follow Henry's law and be dependent on pressure, temperature and salinity. The greater the quantity of sodium chloride (or other substances) in the water, the less will be the dissolved carbonic acid. In one litre of seawater there is ca. 0.3 cc. carbonic acid physically absorbed. The remaining quantity (ca. 150 times as much) occurs either as ions: HCO'_3 or CO''_3 in dissociation-equilibrium with calcium ions (or with other kations) or as undissociated carbonates or bicarbonates.

Since now we must consider, as Fox [1909] maintains on the basis of the modern theory of ions, that all the components of seawater are in mutual equilibrium, any change in the quantity of a single one of the components will alter the whole equilibrium. For example, if we remove a portion of the physically absorbed carbonic acid, some H_2CO_3 will at once be split up into water and CO_2, until the proportion between CO_2 and H_2CO_3 again becomes the same; at the same time, the remaining ions and molecules will adapt themselves to the altered concentrations.

If calcium carbonate is dissolved in water, it becomes hydrolysed to calcium hydrate and acid carbonate, each of which will be dissociated. Introducing the dissociation constants we find [Ruppin 1909 p. 290—291], that a solution saturated at 18° — which contains 0.0131 gm. $CaCO_3$ per litre — will contain ca. 10^{-4} gm.-molecules of hydroxyl, whilst pure water has 10^{-7}; thus, the solution reacts strongly alkaline. When carbonic acid is passed through the water, much more carbonate is dissolved. Schloesing [1872 p. 70] has found, that the empirical equation:

$$x^{0.37866} = 0.92128\ (y - 0.0131)$$

holds good at 16° C., where x denotes the pressure of carbonic acid in atmospheres and y the amount of $CaCO_3$ in gm. per litre. If the solution is in equilibrium with an atmosphere containing $3^0/_{00}$ CO_2, we can calculate, on the basis of some few presuppositions, that the hydroxyl ion concentration will be $10^{-5.8}$, the hydrogen ion concentration therefore $10^{-8.3}$. This concentration corresponds approximately to what has been found in the seawater investigated on the Thor Expedition. If, in addition to water, carbonic acid and chalk, other salts also occur, the conditions become too complicated to be calculated.

III. The Colorimetric Method of Measurement.

For measuring the hydrogen ion concentration in seawater only the colorimetric and the electrometric methods can be used.

As already mentioned in detail, seawater contains a quantity of acid and normal carbonates which occur in such abundance, that they are able in nature to regulate the hydrogen ion concentration, so that it does not change appreciably, even when the amount of carbonic acid is increased by the respiration of

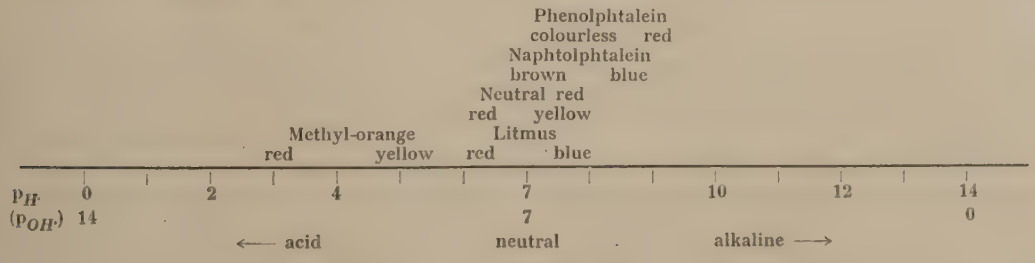
animals or reduced by loss to the atmosphere. On the other hand, if a sample of seawater is taken, the amount of "buffer" substance in this restricted volume of water will be far from sufficient to maintain the hydrogen ion concentration constant. After a couple of days already most samples of water will have become more acid. It is necessary, therefore, to measure the hydrogen ion concentration on board and immediately after the water-bottle has been taken in.

In the case of the colorimetric method the determination can be made easily and quickly even on a ship in a strong seaway, whereas the electrometric method requires very careful management and still conditions for the adjustment of the measuring apparatus and must therefore be said to be unemployable on board. As the fundamental method, however, we cannot do without it, for it is much more under control than the colorimetric method and its results are more accurate and can be calculated more easily; but when the magnitude of the sources of error in the colorimetric method have once and for all been determined by means of electrometric measurements, the colorimetric method can be used without further control being necessary.

The electrometric method is based on the determination of a difference in electric tension, which according to NERNST is directly proportional to the logarithm of the hydrogen ion concentration in the liquid investigated. The concentration is best calculated im gm.-equivalents in one litre of solution and is often written as a power of 10. In accordance with the proposal of S. P. L. SØRENSEN the hydrogen ion concentration is expressed by merely stating the numerical value of the exponent of this power. This is called the hydrogen ion exponent and is indicated by p_H; apart from the first sign it is just the logarithm of the number of gm.-equivalents of hydrogen ions per litre. In this way we are able to represent the proportion between concentration and tension graphically by a straight line and all curves for the actions of the ions obtain a comprehensible form. Thus, n/1000 hydrochloric acid (1/1000 gm.-equivalents in a litre), which may be considered as completely dissociated, has $p_H = 3$, as $1/1000 = 10^{-3}$.

The colorimetric method, which is based on the long known condition that certain colouring matters change colour on the addition of acid or base, has been specially developed at the Carlsberg Laboratory for physiological purposes [S. P. L. SØRENSEN 1909 p. 1; 1909 a p. 131] and later for hydrographic investigations [S. P. L. SØRENSEN and S. PALITZSCH 1910 p. 8 or 1910 a p. 387].

When acid is added to an alkaline solution, which colours red with phenolphtalein, until the colour changes, this does not mean that the solution is neutral, but simply that its hydrogen ion concentration has increased — or expressed in another way, that its hydroxyl ion concentration has decreased — so much, that the phenolphtalein no longer colours the solution red; this will be the case as soon as the hydrogen ion concentration of the solution is ca. 10^{-8} or above, that is, as soon as the p_H of the solution is ca. 8 or less, In an analogous manner an acid solution is coloured red by methyl-orange but as soon as the hydrogen ion concentration has decreased to $10^{-4.5}$, p_H thus risen to 4·5, the solution will be coloured yellow by methyl-orange, although the solution is still far from being neutral ($p_H = 7.07$).



In the figure p_H is marked off along the straight line and the indicators are written above the hydrogen ion concentrations at which their change of colour takes place. It is seen, that only litmus and

neutral red of the indicators noted lie just over the neutral point. In addition to these two a number of indicators are mentioned, with which the change of colour lies at other hydrogen ion concentrations, so that a suitable indicator can be used for each single case.

By merely adding these indicators to the solution required to be investigated we obtain, however, only an estimate of its hydrogen ion concentration; a truly quantitative examination can only be made by means of liquids for comparison. For this purpose solutions of simple compounds are used, which can readily be prepared chemically pure and in which the hydrogen ion concentration can be measured exactly by the electrometric method. In the Études enzymatiques II [S. P. L. Sørensen 1909 p. 35 or 1909 a p. 167] seven of these solutions have been described, from which by mixing two and two we can prepare any desirable hydrogen ion concentration between $10^{-1.04}$ (n/10 *HCL*) and $10^{-13.07}$ (n/10 *NaOH*); in such a way also that these mixtures contain the already mentioned "buffers". Owing to the action of the buffers even a small inaccuracy in measuring will give the desired hydrogen ion concentration, as a considerable quantity of acid or base is required to make a measurable difference in p_H. At the same time the liquids for comparison keep longer, as their hydrogen ion concentration does not change appreciably with a little alkali from the glass or any carbonic acid from the air. The p_H of the mixtures has been found electrometrically by numerous and careful measurements.

The colorimetric determination of the ion concentration of a solution is then made in the following way; first, the approximate value of p_H is found by testing with different indicators, e.g. methyl-orange which perhaps becomes yellow; p_H is then over 4; if the sample is also colourless with phenolphtalein, p_H is less than 8. A sample of water from the Skager Rak, for example, becomes greenish with naphtolphtalein, and this indicator can then be used for more exact measurement, being colourless for p_H less than 4, greenish for p_H just at 8 and blue for p_H greater than 8. Thus, 10 cc. are poured into a test-tube of the comparative liquids which have p_H a little greater and a little less than 8. To these and to 10 cc. of the seawater 6 drops of naphtolphtalein solution are added and on comparing the tints we find, for example, that the sample is greener than a mixture of 6.0 cc. borate and 4 cc. hydrochloric, but bluer than a mixture of 5.8 cc. borate and 4.2 cc. hydrochloric. The p_H of the seawater thus lies between the p_H of these two mixtures, which can be found from Table I. (see p. 245).

As seawater is almost colourless and does not contain colloid substances, which can combine with the indicators, it is excellently suited for the colorimetric method of measurement; its high salinity, however, leads to the so-called "salt error" having a determinative influence.

We find, namely, that most of the indicators change their tint of colour on the addition of a large quantity of salt, and this arises not only from a change in the hydrogen ion concentration of the solution with the addition of salt, but also from the fact, that the colour of the indicators is affected by salts independently of the action of the hydrogen ions. As, however, the greater part of the salts of the seawater consists of sodium chloride and the proportions of the salts are very much the same, even if the quantity of the total salts varies, we are able in this case to get over the difficulty by finding a correction which can be added to or subtracted from the p_H found to give the actual p_H. S. P. L. Sørensen and Palitzsch have determined the salt error for several indicators. Of greatest importance for seawater are naphtolphtalein and phenolphtalein. The correction for these is given in Tables I and II. (Published by S. P. L. Sørensen and S. Palitzsch 1910 p. 21).

As will be seen from the tables, the salt error does not depend on p_H but only on the salt concentration. As the largest correction is 0.22, differences of some few per mille salt will only give an inconsiderable difference in p_H and we are thus able with sufficient exactness to interpolate both for the intermediate salt concentrations and those lying beyond.

The corrections given in the Tables have been found by comparison of the values for p_H, determined by electrometric measurements, with those found for the same samples of seawater by the colorimetric method.

Table I.

Borate mixtures; α-Naphtolphtalein.

Composition of the borate mixture	The ion exponent p_H of the borate mixture		
	uncorrected	corrected for the salt error	
		35‰ salt (corr. = −0,22)	20‰ salt (corr. = −0,17)
5.25 cc. borate + 4.75 cc. HCl	7.62	7.40	7.45
5.3 „ „ + 4.7 „ „	7.71	7.49	7.54
5.4 „ „ + 4.6 „ „	7.84	7.62	7.67
5.5 „ „ + 4.5 „ „	7.94	7.72	7.77
5.6 „ „ + 4.4 „ „	8.03	7.81	7.86
5.8 „ „ + 4.2 „ „	8.17	7.95	8.00
6.0 „ „ + 4.0 „ „	8.29	8.07	8.12
6.25 „ „ + 3.75 „ „	8.41	8.19	8.24
6.5 „ „ + 3.5 „ „	8.51	8.29	8.34

Table II.

Borate mixtures; Phenolphtalein.

Composition of the borate mixtures	The ion exponent p_H of the borate mixture		
	uncorrected	corrected for the salt error	
		35‰ salt (corr. = −0,21)	20‰ salt (corr. = −0,16)
6.0 cc. borate + 4.0 cc. HCl	8.29	8.08	8.13
6.25 „ „ + 3.75 „ „	8.41	8.20	8.25
6.5 „ „ + 3.5 „ „	8.51	8.30	8.35
6.75 „ „ + 3.25 „ „	8.60	8.39	8.44
7.0 „ „ + 3.0 „ „	8.68	8.47	8.52
7.25 „ „ + 2.75 „ „	8.74	8.53	8.58
7.5 „ „ + 2.5 „ „	8.80	8.59	8.64
8.0 „ „ + 2.0 „ „	8.91	8.70	8.75
8.5 „ „ + 1.5 „ „	9.01	8.80	8.85
9.0 „ „ + 1.0 „ „	9.09	8.88	8.93
9.5 „ „ + 0.5 „ „	9.17	8.96	9.01
10.0 „ „	9.24	9.03	9.08

IV. Practical Application of the Method.

The following method of measuring the hydrogen ion concentration of seawater has been worked out on the basis of the principles discussed in the foregoing [S. P. L. SØRENSEN and S. PALITZSCH 1910]; it has proved to be eminently serviceable on board the research steamer "Thor". In the following detailed description I have felt it necessary not only to include all details but also to remark upon such conditions as appeared to have importance for the convenient and accurate use of the method on board ship.

As the hydrogen ion concentration of the seawater investigated lay between $p_H = 7.95$ and $p_H = 8.35$ (see p. 247), only mixtures of borate and hydrochloric acid were used, with the indicators naphtolphtalein[1] [S. P. L. SØRENSEN and S. PALITZSCH 1910 p. 1 or 1910 a p. 381] and phenolphtalein. (Phosphate mixtures[2] were only used for the hydrogen sulphide samples from the Black Sea.)

The indicator solutions were prepared by dissolving 0.2 gm. naphtolphtalein or 0.5 gm. phenolphtalein in 300 cc. 93% alcohol and diluting with water to half a litre.

The n/10 hydrochloric acid was carefully standardized by means of sodium oxalate.

The borate solution was prepared by dissolving 0.2 gm.-molecules of boric acid (12.404 gm.) in 100 cc. normal sodium hydrate solution and diluting with boiled water to one litre. The boric acid used fulfilled the requirements of purity prescribed by S. P. L. SØRENSEN [1909 p. 36 or 1909 a p. 172].

Distilled water was used for both solutions and was thoroughly boiled in a tinned copper retort to remove the carbonic acid. To prevent the carbonic acid of the air coming in contact with the liquid on pouring it from the measuring retort into the retaining bottles, a short and a long tube were inserted into the cork of the retort, so that the air of the retaining bottle, which beforehand had been freed of carbonic acid, rose up through the long tube, whilst the liquid ran in through the short one without being exposed to the action of the outer air containing carbonic acid. The air in retorts, bottles and pipettes used was

[1] The colouring matter obtained in the trade from C. A. F. KAHLBAUM, Berlin.
[2] For the preparation of this see S. P. L. SØRENSEN 1909 p. 34 or 1909 a p. 169.

freed from carbonic acid by first leading the air through a strong solution of potassium hydrate and then through water to wash it.

The sodium hydrate solution used for the borate solution must not contain carbonate and was prepared by dissolving 100 gm. sodium hydrate e natrio (Kahlbaum) in 125 gm. water in a narrow cylinder, which was kept closed by a glass stopper. The solution was about 17 normal and as sodium carbonate is quite insoluble in such a concentrated solution and falls to the bottom in the course of two days, the clear liquid above will be perfectly free of carbonate and easily drawn off with a pipette.

The bottles in which the liquids for comparison are kept were closed with a double-bored stopper of rubber. On the one side was inserted a glass tube which reached the bottom and through which the burette was filled; on the other side was a tube with soda-lime, so that the air drawn into the bottle was freed from carbonic acid. For measuring, burettes were used which were filled from below and which uppermost contained a stick of soda-lime, so that the air drawn in on emptying the burette might be free of carbonic acid.

The solutions were prepared on land. On testing them after the return home the mixtures used had not altered appreciably.

It would be very inconvenient, often indeed impossible, to measure off the liquids for comparison on the voyage. This was avoided by using bottles of ca. 150 cc. which were filled with the liquids for comparison when the ship lay in harbour. There was most use for 5.6-5.7-5.8-6.0-6.2-6.4-6.7-7.0 borate and hydrochloric acid. 5.6 cc. borate and hydrochloric means a mixture of 5.6 cc. borate solution and (10—5.6 =) 4.4 cc. hydrochloric. Measuring off 150 cc. at once instead of 10 cc. each time led also to greater exactness, as an error of 0.1 cc. thus only meant an almost indistinguishable change in p_H. The bottles were provided with a double-bored rubber stopper; in the one opening was inserted a small glass tube containing granulated soda-lime, in the other a glass-tube which reached to the bottom and was closed at the upper end by a short piece of rubber tubing and a piece of glass. When the liquids for comparison were to be used, this piece of glass was removed and a pipette of 10 cc. inserted in the tubing; when the pipette was sucked full, the air which entered the bottle was obliged to pass through the tube containing the soda-lime and thus became free of carbonic acid. The bottles were kept in a small wooden box and fastened by copper-wire, which is not so heavy and does not take up so much space as wooden partitions.

During the comparison of the colours the test-tubes were placed in a rack, so constructed that the tubes stood sloping at an angle of ca. 45° with the table. The base of the rack on which the tubes rested was covered with milk-white wax-cloth, so that the colours could be seen against a light background. It proved necessary to use wax-cloth or celluloid, as paper is spoilt by the damp which is inevitable on board ship. To use a swinging tube-rack, so that the tubes might be vertical when filled and sloping when measured, was found to be not so convenient, as such racks are difficult to fasten up and swing backwards and forwards with the rolling of the ship. The test-tubes are kept closed with corks to keep out dust and the carbonic acid of the air; for seawater the action of the latter has but little importance as a rule, as seawater has very nearly the same carbonic acid tension as the atmosphere. The test tubes were of thin and colourless glass, and their diameter varied but little (from 21 to 22 mm.), otherwise the weight and thickness of the volume of liquid will be so different that the comparison becomes very difficult. A ring was marked with glass-ink on the test-tube for the seawater sample, so that the amount up to this mark was just 10 cc. The tube was filled directly from the water-bottle, 6 drops of naphtolphtalein or 8 drops of phenolphtalein added from a small drop-bottle with ground glass stopper, and the tube was placed among the similarly coloured comparative liquids, in such a position, that the liquid on the one side was stronger red (phenolphtalein), that on the other side less red. If the colours were in the right order there might sometimes be a doubt as to whether the sample had really been placed correctly,

but on moving the sample from the one side to the other the difference in colour was seen very distinctly. By moving the sample forwards and backwards, it could likewise be seen whether the colour came nearest to the stronger or weaker coloured liquid and after some practice one could thus make a very sharp reading. The error in reading can scarcely be considered as greater than ± 0.04 in the value of $p_{H'}$.

The temperature of the seawater in the tube always rose a little before the reading was completed, especially as it was not possible as a rule to leave the water-bottle immediately after the sample was taken. These temperature changes however were seldom so great as to make any measurable changes in the $p_{H'}$ of the seawater, which in fact changes very little with the temperatrre.

V. The Values of the Hydrogen Ion Concentration in Seawater, found on the Expedition.

The results of the observations made on the Expedition are brought together in Table 3. The hydrogen ion concentration is expressed by the value, corrected for the salt error, of $p_{H'}$. The depth is given in meters. The stations are only noted by the number to be found in the main tables, where the data regarding place, time, salinity etc. can be found. As will be seen, the first observations were made in the Atlantic, in part in the Bay of Biscay and in part off the coasts of Portugal and Morocco, whilst the greater number of the stations are in the Mediterranean, both in the western and eastern basins; from the Sea of Marmora, Bosphorus and the Black Sea there are some few observations.

The sections I and II have also been drawn to give a general view of the conditions; the curves on these are drawn through depths with the same hydrogen ion concentration. Further, for comparison, section III shows some measurements from the Norwegian Sea and the waters between the Færoes and Shetland [1].

It appears from the table as from the curves, that the variation in the amount of the hydrogen ion concentration was on the whole not considerable, though quite recognisable. The lowest value observed for $p_{H'}$ was 7.95 (excluding the Black Sea) and the highest value was 8.35.

For the surface water of the Skager Rak, the southern part of the North Sea and the western part of the Baltic, a $p_{H'}$ was found which was less than 8.08 (as a rule between 8.00 and 8.05). This water therefore is not coloured by phenolphtalein. In the Norwegian Sea the surface water was a little more alkaline; $p_{H'}$ lay between 8.08 and 8.13; off the Moray Firth, 20 miles from land, $p_{H'}$ was however 8.15 to 8.18. In the Atlantic $p_{H'}$ rose from north to south; furthest north it was almost as in the Norwegian Sea, except in a fjord (Vaag Fjord in the Færoes) with water very rich in oxygen, where $p_{H'}$ was found to be 8.22 to 8.24. In the Bay of Biscay and along the coast of Portugal $p_{H'}$ reached up to 8.25, which is the average value for the surface water in the Mediteranean, though the water in the eastern part is the most alkaline ($p_{H'}$ equal to ca. 8.27). All the surface samples from the Mediterranean are thus coloured distinctly red with phenolphtalein [2]. The most alkaline water was taken in the southern part of the Marmora Sea, Bosphorus and Black Sea; $p_{H'}$ was found to be ca. 8.35 in the surface water at these places.

With very few exceptions the hydrogen ion concentration increased (thus $p_{H'}$ decreased) from the

[1] The temperatures and salinities have been published in Bulletin hydrographique, Juillet 1909—Juin 1910, p. 43—46. The positions of the stations used for the section are No. 11, 61° 19′ N. — 7° 03′ W.; No. 21: 61° 27′ N. — 4° 33′ W.; No. 27, 60° 38′ N. — 6° 28′ W; No. 28; 59° 33′ N. — 6° 23′ W.; No. 29: 58° 10′ N. — 6° 12′ W. The stations were investigated in May to June 1910.

[2] Seawater with a salinity of ca. 35‰ and with $p_{H'}$ higher than 8.06 is coloured red with phenolphtalein.

surface down towards the bottom; p_H was found to be from 8.07 to 8.09 almost everywhere at the bottom of the Mediterranean and the water here was thus so alkaline that it could just be coloured faintly with phenolphtalein. In the Atlantic the bottom water showed a much lower p_H at several places; in the Bay of Biscay and off the coast of Portugal, for example, water was taken from a depth of 2000 meters which had p_H only 7.95. (The ice-cold water from 900 meters in the Norwegian Sea also had this p_H). The transition from the higher p_H of the surface-water to the lower at the bottom was as a rule quite gradual, though the greatest differences for the same difference in depth lay in the uppermost layers (for the details see sections I, II and III).

Black Sea. St. No. 172 was the only station taken in the Black Sea. From greater depths than 180 meters the water contains hydrogen sulphide and it was to be expected, therefore, that it would be more acid than ordinary seawater. The samples from 1000 and 800 meters, immediately on being taken up, were tested both with neutral red and with naphtolphtalein as indicators and phosphate mixtures as the comparative liquids[1]; they gave almost the same colour as the mixture "8 secondary—2 primary phosphate". Corrected for the salt error p_H thus becomes 7.26. This water, which was the most acid of all the seawater investigated on the Expedition, is thus nevertheless still more alkaline than a neutral solution, in which as mentioned p_H is 7.07. As the station was examined at night and the colour, both with neutral-red and with naphtolphtalein in liquids with p_H equal to ca. 7.3, is orange to yellow, shades of colour difficult to distinguish by artificial light, the determination could not be very exact. In the morning a white precipitate had appeared in the samples from the three greatest depths (1000—800—600) and they had now become more alkaline with p_H equal to 7.80 when tested with naphtolphtalein; the remaining samples were perfectly clear and showed on comparison:

Meters	400	300	200	100	85	75	50	25	10	0
p_H	7.53	7.55	7.67	7.86	7.99	8.03	8.15	8.19	8.25	8.34
Oxygen %	—	(H_2S)	—	31.7	59.8	74.3	91.8	111.6	94.4	94.2

(The samples from 25—10—0 meters were tested with phenolphtalein and borate mixtures, the others with naphtolphtalein and phosphate mixtures).

It will be seen from Pl. XIX, where the depth in meters is marked off along the ordinates and in the three curves respectively p_H, percentage of oxygen and quantity of chlorine along the abscissae, that the hydrogen ion concentration seems in this case to be dependent on the oxygen contents of the water.

No distinct connection between the quantity of oxygen and the hydrogen ion concentration or between the latter and the temperature or chlorine contents seems, however, to be present in the values found for the other stations.

At some stations, nevertheless, conditions were found which perhaps merit special mention.

At St. 91 (cf. Pl. XIX) in the Atlantic, south-west of Cadiz, it will be noticed, for example, that the least alkaline water, which here contrary to the usual does not occur at the bottom, corresponds to a marked minimum for the oxygen.

Meters	400	600	800	1000	1200
p_H	8.04	7.98	7.95	7.98	8.01
Oxygen %	76.9	67.4	63.5	64.3	67.7
Chlorine ‰	19.76	19.71	19.83	19.94	20.16

At the stations Nos. 80 and 81 (see Pl. XIX), also in the Atlantic, still more distinct oxygen minima occur however (at a depth of ca. 1000 meters), without these being accompanied by any corresponding minimum for p_H, which decreases evenly towards the bottom.

[1] For the preparation and use of phosphate mixtures see: S. P. L. Sørensen, 1909 p. 34.

Meters	400	600	800	1000	1200	1500	2000	
p_H	8.04	—	8.01	8.01	7.98	7.95	7.95	
Oxygen %	78.9	71.4	68.3	67.5	68.6	74.3	79.1	Station
Chlorine ‰	19.69	19.79	19.94	19.94	19.93	19.65	19.43	No. 81

There can be no talk of any general rule, therefore, but some other examples will be given below, which might suggest a connection between the quantity of oxygen and the hydrogen ion concentration.

On the other hand, if we seek for a condition which differs at the stations mentioned, we may notice that at St. 91 there is a chlorine minimum in the neighbourhood of the minimum for oxygen, whereas at the stations 80 and 81 there is a chlorine maximum at the same depth as the oxygen minimum. In the Mediterranean a chlorine maximum is frequently found in the neighbourhood of the oxygen minimum but almost never a chlorine minimum.

The minimum observed for p_H at 800 meters at St. 107 (see Pl. XIX) does not correspond to any maximum or minimum for the other dimensions measured (the oxygen minimum lies at 400 meters, a temperature minimum at 1000 meters). Nor, seemingly, can the rarely observed condition, that the bottom-water is a little more alkaline than the overlying layers, as at Stations 87 and 107, be explained on the basis of the simultaneously measured temperatures, salinities or amount of oxygen. This applies also to two of the stations investigated on the cruise to the Færoes in 1910: Nos. 13 and 14; the conditions at St. 14 are graphically represented on Pl. XIX; at St. 13. 61°08′ N.—8°26′ W. The conditions were:

Meters	0	25	50	75	100
p_H	8.13	8.13	8.15	8.18	8.18
Oxygen %	100.1	98.7	98.3	98.1	95.7
Salt ‰	35.27	.26	.22	.21	.24

Station 107 had the same position as St. 223 but the first was investigated on 25/6, the second on 5/9 (see Pl. XIX).

	Meters	0	10	25	50	75	100	200	300
St. 107	p_H	8.24	—	8.22	8.13	—	—	8.09	8.09
	Oxygen %	—	98.3	—	95.6	82.1	74.5	71.4	69.4
St. 233	p_H	8.28	8.26	—	—	8.22	8.22	8.20	8.14
	Oxygen %	98.1	98.0	107.0	102.5	93.6	88.5	73.1	68.1

It is seen that the surface-water at 223 is a little more alkaline than at 107, but especially, that the water at 223 right down to 200 meters is considerably alkaline, whereas at 107 it is already at this depth almost just as little alkaline as the bottom-water. This is accompanied by a change in the amount of oxygen, which during the period from June to September has greatly increased at the depths 50 to 200 meters. (The temperature has risen at the same time and the amount of chlorine decreased in the uppermost layers),

Further, if we compare St. 230 with the stations 96 and 98 (where 230 was taken about the same time as 223 and 96 and 98 at the same time as 107), it is seen that p_H has only altered a little in the intermediate period.

	Meters	0	25	50	100	150	200
St. 98	p_H	8.24	8.22	—	8.15	—	8.13
	Oxygen %	101.3	98.4	95.6	82.2	77.4	76.4
St. 230	p_H	8.24	—	8.20	—	8.15	8.13
	Oxygen %	97.1	94.6	94.8	83.0	80.4	75.4

Here the difference in percentage of oxygen is also much less than at 107 and 223, and especially, there is no water-layer here as at 223 which is "oversaturated" with oxygen. (The meaning of this expression is explained in the section on the determination of oxygen). The layer oversaturated with oxygen, which occurs almost everywhere in the Mediterranean at a depth of ca. 55 meters, seems to be accompanied by a plentiful occurrence of vegetable plankton, which develops oxygen and at the same time absorbs carbonic acid, so that the water becomes more alkaline.

The two stations 170 and 175 (see Pl. XIX) both lie in the Sea of Marmora, but the unusually low hydrogen ion concentration (thus the high p_H) at 170 is not found again at 175.

	Meters	0	10	15	20	25
St. 170	p_H	8.35	8.33	8.26	8.22	8.13
	Oxygen %	99.2	105.4	106.3	107.7	92.6
St. 175	p_H	8.23	8.20	—	8.13	8.09
	Oxygen %	96.1	86.5	96.6	97.5	88.1

The temperature and amount of chlorine are almost the same at the two stations, but the amount of oxygen is very different; at St. 170 layers of water occur at 10 to 20 meters which are greatly oversaturated with oxygen.

In the water of Vaag Fjord in the Færoes, where (in May 1910) an unusually great supersaturation with oxygen was found, there was also a hydrogen ion concentration ($p_H = 8.23$) which was distinctly less than the concentration in the surface-water in the neighbourhood of the Færoes ($p_H = 8.08—8.18$).

As will be seen from these examples, there seems to be a certain connection between a high quantity of oxygen and a high p_H but as already mentioned no general rule can be detected. Unfortunately, I have not determined the carbonic acid tension nor the alkalinity in the water-samples investigated on the Expedition; it is probable, as already mentioned, that there is a natural connection between these two factors and the amount of the hydrogen ion concentration.

The hydrogen ion concentrations found on the Thor Expedition are, as will be seen, in good agreement with the results of the investigations mentioned in the historical section.

Ringer (see p. 239) found concentrations from 0.58×10^{-8} to 1.40×10^{-8}; expressed in p_H these are values from 8.24 to 7.86. Although the water-samples examined, in regard to nature and place taken, differ for the most part greatly from the sea-water examined by the Expedition yet p_H is only a little different (7.86—8.24 and 7.95—8.35).

Apart from a few observations (Loeb [1903 p. 637], Fox [1909 p. 30]), not confirmed later, all investigations into the reaction of seawater have shown that it is slightly alkaline.

Since the seawater stands in such intimate contact with the organisms of the sea, not only bathing them but also passing through their gills and in part the bodies of the invertebrate animals, it does not seem too presumptuous to compare the seawater with other physiological liquids. It appears from the observations described in the foregoing that seawater, like these liquids, possesses a considerable power of regulating its own hydrogen ion concentration, although this power[1] is not so marked as for example in the case of the blood.

In both the seawater and the blood the physical and chemical nature must be quite definite, in order that the animals which live in and from them may thrive. In experiments with artificial seawater or aquaria, therefore, it is very necessary to procure and maintain a definite hydrogen ion concentration, so long as the experiment lasts, and it must be remembered that this concentration is not the same for surface organisms as for bottom animals. Even if the difference is small, it is yet large enough, as Loeb and Bethe have shown, to have a determinating influence.

To my highly respected teacher Professor S. P. L. Sørensen, who with the greatest kindness gave the necessary leisure for the investigations, I would offer here my most sincere thanks. I also wish to express my thanks to Dr. Johs. Schmidt for giving me the opportunity to test the colorimetric method of measuring the hydrogen ion concentration of seawater on the Thor Expedition in 1910.

[1] This property seems to be supported by various outer conditions; thus, J. Loeb (University of California Publications. Physiology. Vol. 1, Nr. 15 p. 139 (1904), Pflügers Archiv 101, p. 304 (1904)), has observed that algae (Ulva) in addition to assimilating carbonic acid also secrete an alkaline substance in the light.

VI. Summary.

1. Historical introduction. Alkalinity must not be confused with hydrogen ion concentration. Determination of the alkalinity gives information regarding the amount of bases which are united with carbonic acid, but not regarding the acid, neutral or alkaline reaction of the seawater. A certain and quantitative determination of the latter can only be obtained by measurement of the extent of the hydrogen ion concentration.

A few qualitative investigations have shown that the seawater has a slightly alkaline reaction; by means of the electrometric method on land Ringer has determined the hydrogen ion concentration in seawater samples kept in bottles for some time.

It appears clearly from the numerous experiments made by Loeb and Bethe, that biological processes in the sea have a marked optimum with respect to the hydrogen ion concentration.

2. Theoretical remarks. The hydrogen ion concentration, which has determinative influence on almost all physiological and biological processes, is not only dependent on the quantity of acids and bases, but also and to an essential extent on the dissociation of these as well as on the dissociation and quantity of all the other substances present.

For the hydrogen ion concentration of seawater the principal role is played by the mutual relations of the carbonic acid and calcium salts in regard to equilibrium and dissociation. The conditions are however too complicated to be estimated.

3. The colorimetric method of measurement. By means of the colorimetric method the determination of the hydrogen ion concentration of seawater can be carried out easily and expeditiously, even on a ship in a heavy sea, whereas the electrometric method is too delicate to be used onboard. Owing to its greater accuracy, however, the latter is used as controlling and fundamental method for the colorimetric.

On the proposal of S. P. L. Sørensen, the hydrogen ion concentration is expressed most conveniently by the numerical value of the exponent of the power of 10, which indicates the number of gm.-equivalents of hydrogen found as ion in each litre. This number is called the hydrogen ion exponent and is indicated by p_H.

The colorimetric method is based on the long known condition, that certain colouring matters change colour and change it gradually on the addition of acids or bases. With a suitable indicator we can colour both the seawater and a series of liquids for comparison, in which the hydrogen ion concentration has been measured exactly by means of the electrometric method. On comparing the tints of colour we can readily find the comparative liquid, which has the same or almost the same hydrogen ion concentration as the seawater. The correction due to the action of the salts on the colour tints of the indicator (salt error) is determined by comparison of the values for p_H found by means of the electrometric method with those found for the same sample of seawater by the colorimetric method.

4. The practical application of the method. A detailed account is given, including not only all details but also the conditions which seemed of importance for the accurate carrying out of the method on board ship.

As indicators naphtolphtalein and phenolphtalein were used and as liquids of comparison mixtures of sodium borate solution and hydrochloric acid.

5. The values for the hydrogen ion concentration of seawater, found on the Thor Expedition.

On the summer cruise of 1910 water-samples were investigated from the Sound, Skager Rak· North Sea and the western part of the Baltic (only surface-samples from all these places), from the Norwegian Sea east and south of the Færoes, from the Atlantic north of the Hebrides and on the stretch from Falmouth to Gibraltar, from the Mediterranean, and also from the Sea of Marmora, the Bosphorus and Black Sea.

From the observations made it appears that the variation in the amount of the hydrogen ion concentration was on the whole not very considerable, yet quite determinable. The lowest value observed for $p_{H.}$ was 7.95 (excluding the Black Sea) and the highest value 8.35. Expressed in words this means that all the seawater investigated was alkaline and for the most part even so alkaline that it was coloured by phenolphtalein.

It may be laid down as a general rule, that the water becomes less and less alkaline from the surface down towards the bottom and that the transition from the more alkaline reaction of the surface to the less alkaline of the bottom-water (from the highest to the lower $p_{H.}$) was always quite even and such that the change in the hydrogen ion concentration for the same difference in depth was considerably greater in the upper than in the lower layers.

In contrast to all the other surface-water samples examined on the Expedition the surface-water in the neighbourhood of Denmark (the Sound, Skager Rak, southern part of the North Sea and Western part of the Baltic) was too little alkaline ($p_{H.}$ = 8.00—8.05) to be coloured by phenolphtalein. On passing from the Norwegian Sea to the Atlantic and from there into the Mediterranean we meet with increasingly alkaline surface-water, until in the Black Sea we find it so alkaline ($p_{H.}$ = 8.35) that it is coloured strongly red with phenolphtalein.

In the ice-cold bottom water of the Norwegian Sea as also in the branch of the cold Norwegian Sea water which pushes into the Atlantic south of the Færoes, a relatively high hydrogen ion concentration ($p_{H.}$ = 7.98—7.95) was measured. Here also, however, the hydrogen ion concentration evenly increased ($p_{H.}$ decreased) from surface to bottom.

In the Atlantic (Bay of Biscay and off the coast of Portugal) the water in 1500 to 2000 meters had just as high a hydrogen ion concentration ($p_{H.}$ = 7.95) as that found in the Norwegian Sea in 700—900 meters.

In the Mediterranean, water with so high a hydrogen ion concentration, or expressed in another way water which was so little alkaline, was not once observed; here almost all the bottom-water was so alkaline that it could just be coloured with phenolphtalein ($p_{H.}$ = 8.07—8.09). As Pl. XIX shows, the water became on the whole more alkaline (rising $p_{H.}$) from west to east, both for the surface and the bottom-water.

The Sea of Marmora and the Bosphorus are remarkable for the comparatively strongly alkaline surface-water, just as also

The Black Sea, where, in addition, water containing hydrogen sulphide was taken from depths more than 180 meters, and it also had a very high value for the hydrogen ion concentration; in water from a 1000 meters for example, a $p_{H.}$ was found which was only 7.26. Although this water was thus much more acid (less alkaline) than all the other seawater samples examined, it was nevertheless alkaline, its $p_{H.}$ being still greater than 7.07, which corresponds to the hydrogen ion concentration of the neutral solutions.

Any distinct connection between quantity of oxygen and hydrogen ion concentration or between the latter and the temperature or salinity is not apparent from the values found, but the conditions at some of the stations perhaps suggest, that a higher quantity of oxygen is accompanied by a lower (i. e. more alkaline) hydrogen ion concentration.

Table 3. The Hydrogen ion concentration, expressed in p_H.

St.	80	81	84	87	91	96	97	98	107	118	122	125	126	128	129	131	133	134
Depth: m 0...	8.20	8.22	8.22	8.26	8.24	8.20	8.24	8.24	8.24	8.26	8.29	8.23	8.25	8.23	8.23	8.27	8.27	8.27
— 10...	"	"	8.13	"	"	"	"	"	"	"	8.25	"	"	"	"	"	8.27	8.25
— 25...	"	"	8.08	8.20	"	"	"	8.22	8.22	8.24	"	"	"	"	8.23	8.25	"	"
— 50...	"	8.18	"	"	8.18	"	"	"	8.13	8.24	"	8.19	8.23	8.23	8.23	"	8.21	8.23
— 75...	"	"	"	"	"	"	"	"	"	8.22	8.23	"	"	"	"	"	"	"
— 100...	8.08	8.13	"	8.13	8.13	8.20	8.20	8.15	"	8.19	8.21	"	8.21	8.21	8.21	8.21	8.21	8.21
— 150...	"	"	"	"	"	"	8.15	"	8.09	8.14	"	"	"	"	"	8.19	"	8.21
— 200...	8.08	"	"	8.10	8.08	8.13	8.13	8.13	8.09	8.14	8.21	8.17	8.19	8.19	8.19	"	8.17	8.14
— 300...	"	"	"	"	"	"	8.10	8.09	"	8.12	"	"	"	"	"	8.19	8.12	8.12
— 400...	8.06	8.04	"	"	8.04	"	8.08	"	8.09	8.09	8.19	8.14	8.17	8.19	8.19	"	8.09	8.07
— 500...	"	"	"	"	"	"	"	8.07	8.09	"	8.19	"	8.14	8.17	"	"	8.09	"
— 600...	"	"	"	8.06	7.98	"	8.07	"	8.07	8.07	8.17	8.12	8.12	8.17	"	"	8.09	"
— 700...	"	"	"	"	"	"	"	8.07	"	"	"	"	"	"	"	8.12	"	"
— 800...	8.04	8.01	"	8.04	7.95	"	"	"	8.03	"	8.17	8.12	"	"	8.17	8.09	"	"
— 900...	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	8.09	"	"
— 1000...	8.01	8.01	"	8.01	7.98	"	"	"	8.07	8.07	8.12	8.09	"	8.14	8.14	"	"	"
— 1200...	7.98	7.98	"	8.01	8.01	"	"	"	8.09	"	8.07	"	"	8.12	8.14	"	"	"
— 1500...	7.95	7.95	"	8.06	"	"	"	"	8.12	"	"	"	"	8.07	8.12	"	"	"
— 2000...	7.95	7.95	"	"	"	"	"	"	8.07	8.07	"	"	"	"	8.09	"	"	"
— 2500...	"	"	"	"	"	"	"	"	"	8.07	"	"	"	"	8.07	"	"	"
— 3200...	"	"	"	"	"	"	"	"	"	"	"	"	"	"	8.07	"	"	"

St.	143	145	150	154	170	171	172	175	181	183	189	194	195	202	204	209	214	217	223	230
Depth: m 0...	8.27	8.27	8.31	8.25	8.35	8.35	8.34	8.23	8.27	8.25	8.29	8.27	8.27	8.21	8.14	8.25	8.25	8.26	8.28	8.24
— 10...	8.25	8.29	"	"	8.33	8.35	8.25	8.20	"	8.25	8.29	"	"	8.21	"	8.23	8.23	8.26	8.26	"
— 25...	8.23	"	8.27	"	8.13[1]	8.31	8.19	8.09[2]	"	8.25	"	"	8.23	8.19	"	8.21	"	8.24	"	"
— 50...	8.23	8.27	8.25	8.29	8.07	8.20	8.15	"	"	8.21	8.25	"	8.21	8.14	"	8.21	8.19	8.20	"	8.20
— 75...	"	"	"	"	"	"	8.03	"	"	"	"	"	"	"	"	"	"	"	8.22	"	
— 100...	8.21	8.23	"	8.25	8.03	"	7.86	8.03	8.25	8.17	8.21	8.25	8.14	8.12	"	8.14	8.14	8.14	8.22	"
— 150...	"	"	"	"	"	"	"	"	"	8.12	8.19	"	"	"	8.09	"	8.12	"	"	8.15
— 200...	8.17	8.23	"	8.23	8.03	"	7.67	"	8.17	8.09	8.19	8.17	8.14	8.07	8.09	"	"	8.14	8.20	8.13
— 300...	"	"	"	8.19	8.09	"	7.55	8.03	"	"	8.17	8.14	"	8.07	"	8.09	"	"	8.14	"
— 400...	8.14	8.21	"	"	"	"	7.53	"	"	"	8.17	8.14	8.12	8.07	"	"	"	"	8.12	"
— 500...	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
— 600...	8.12	8.17	"	"	8.09	"	(7.26)	8.05	"	"	8.17	8.12	8.12	8.07	"	"	"	8.14	8.09	"
— 700...	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
— 800...	"	"	"	"	8.09	"	(7.26)	"	"	"	8.14	8.12	8.12	8.07	"	8.09	"	"	"	"
— 900...	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
— 1000...	8.12	8.14	"	"	8.09	"	(7.26)	8.05	"	"	"	8.09	"	"	8.09	"	"	8.12	"	"
— 1200...	"	"	"	"	8.03	"	"	"	"	"	8.14	"	8.09	"	"	8.12	"	"	"	"
— 1500...	8.09	8.12	"	"	"	"	"	"	"	"	"	"	8.09	"	"	8.12	"	8.12	8.09	"
— 1800...	8.09	8.12	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
— 2000...	"	"	"	"	"	"	"	"	"	"	"	"	8.09	"	"	"	"	"	8.09	"

[1] In 15 m p_H was 8.26.
- 20 - - - 8.22.

[2] - 20 - - - 8.13.

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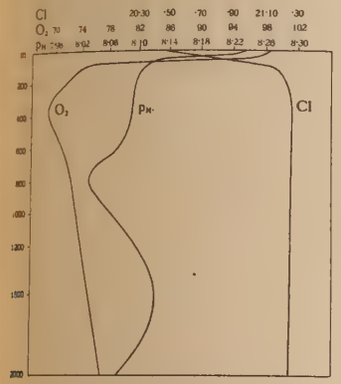
STATIONS AND SECTIONS.



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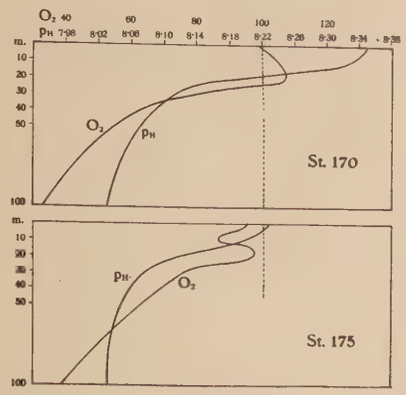

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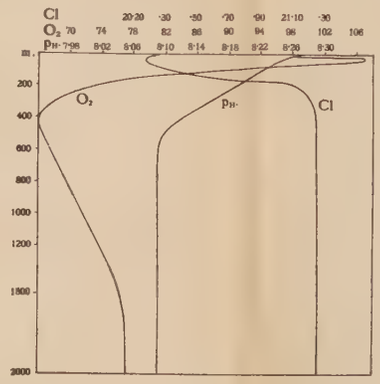

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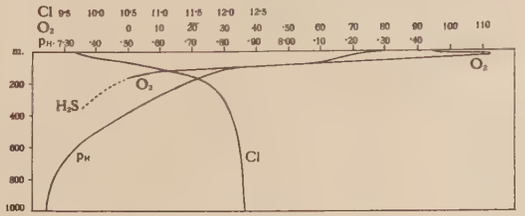

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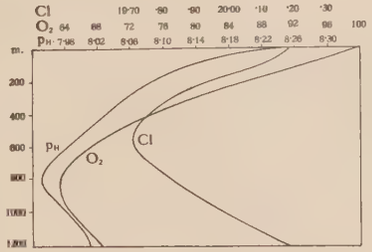
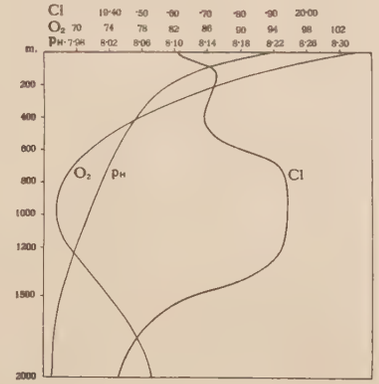
Black Sea



St. 91

St. 14
Norwegian Sea



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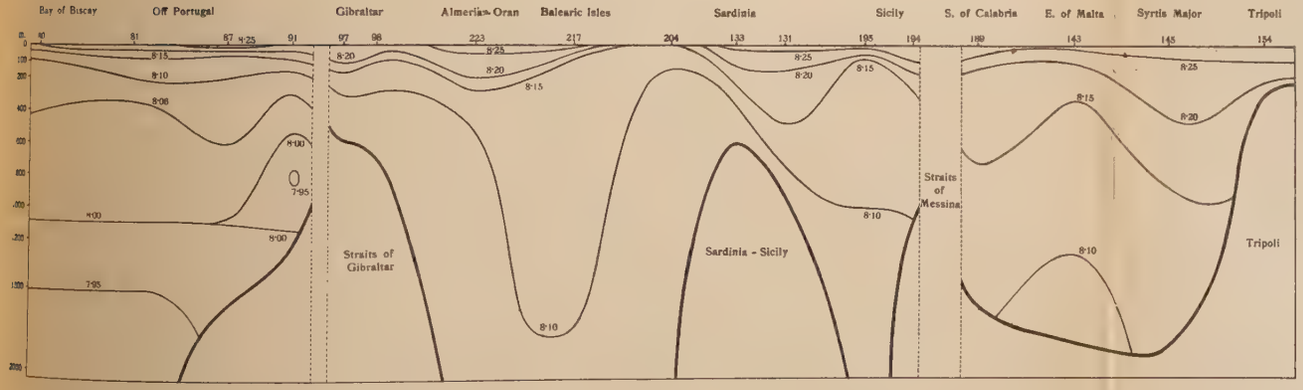
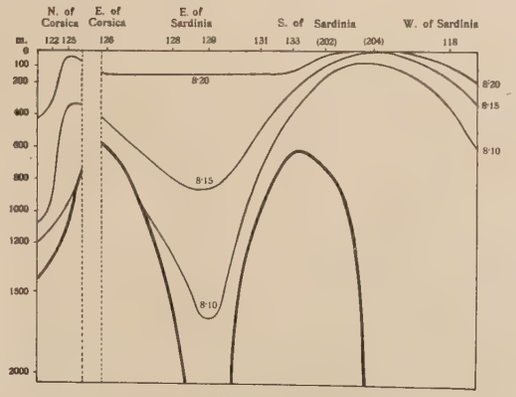


Section I



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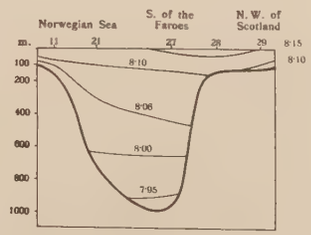

Section III

III.

THE DEPOSITS OF THE SEA-BOTTOM

BY

O. B. BØGGILD

CONTENTS.

		page
I.	Introduction	257
II.	Physical properties of the samples	257
III.	Mineral constituents of the samples	263
IV.	Organic constituents of the samples	264
V.	Concretionary constituents of the samples	266
VI.	Summary	269

I. Introduction.

The material placed in my hands for examination consists of 30 bottom-samples from the "Thor" Expedition. The samples are fairly evenly distributed over the whole of the Mediterranean with exception of the easternmost part, south of Asia Minor, and as they are also taken from widely different depths and at very different distances from land, they afford a good view of the bottom conditions of the Mediterranean as a whole.

In addition to the Mediterranean samples there was also a single sample from the Black Sea and one from the Atlantic, besides a few from the Sea of Marmora and Straits of Gibraltar.

What has been known hitherto regarding the bottom-deposits of the Mediterranean, has been derived mainly from the examination of the samples collected by the Austrian ship "Pola" in the years 1890—93, which were described by Natterer (Denkschr. Akad. Wiss. Wien 59, p. 103, 60, p. 49, 61 p. 23) and by Windt and Berwerth (Anz. Akad. Wiss. Wien, 1901, p. 238 and Denkschr. Akad. Wiss. Wien, 74, p. 285). The "Pola" visited the eastern half of the Mediterranean and collected there a large number of samples, and these received an extremely thorough chemical examination especially at the hands of Natterer, whilst the other two authors mainly restricted their work to the determination of the amount of calcium carbonate.

As will be shown in the sequel, the bottom-soil of the Mediterranean is remarkable everywhere for its great uniformity, which we might expect indeed beforehand, as the physical conditions are practically uniform over the whole of this vast area. The principal factors determining this condition are, on the one hand, the relatively small quantity of material brought down from the land, which again is connected with the small number of rivers flowing into the Mediterranean, and on the other hand, the relatively rich animal-life, which probably cannot be compared with that of the open oceans, but is yet sufficient to give the bottom-samples a distinctly organic character. Of secondary constituents formed later the samples contain but little, but various kinds occur.

II. Physical properties of the samples.

The samples I have had for examination are recorded in the following table, along with their most conspicuous, physical properties; the amount of calcium carbonate is also included, as this more than anything is of importance for the classification of the samples.

No. of the sample	Latitude N.	Longitude	Depth in m.	Percentage of $CaCO_3$	Classification	Colour	Petrographic consistency	Coherency when dry
116	39°27′	5°26′ E	2860	41.5	Globigerina ooze	brown	sandy clay	strongly coherent
126	42 43	9 50	620	26.7	Blue mud	grayish brown	clay	very strongly c.
128	41 01	10 53	1600	48.5	Globigerina ooze	brown	sandy clay	strongly c.
131	38 36	11 00	915	52.6	„ „	„	„ „	„ „
132	38 57	9 47	1227	56.7	„ „	„	„ „	rather strongly c.
133	38 18	9 59	600	48.0	„ „	„	„ „	strongly c.
134	37 37	10 17	410	37.6	„ „	gray-brown	„ „	very strongly c.
137	37 17	10 56	195	43.2	Shallow-water deposit	„ „	coarse sandy clay	loosely c.
138	37 37	11 25	820	53.9	Globigerina ooze	grayish brown	„ „ „	„ „
140	37 29	12 34	112	22.0	Shallow-water deposit	brownish gray	clay	strongly c.
142	35 44	15 07	98	81.3	„ „ „	gray-brown	coarse clayey sand	loosely c.
145	32 38	19 02	1925	67.0	Globigerina ooze	brown	sandy and gravelly clay	„ „
147	31 35	19 02	960	65.5	„ „	„	sandy clay	rather strongly c.
148	30 45	19 02	240	48.4	„ „	„	„ „	„ „ „
150	30 23	19 02	35	91.0	Shallow-water deposit	grayish white	gravel	not coherent
153	32 45	22 41	13	98.5	„ „ „	yellowish white	„	„ „
160	35 59	28 14	3200	34.4	Globigerina ooze	grayish brown	clay	strongly c.
163	37 52	26 22	1180	35.9	„ „	„ „	„	„ „
172	41 32	29 24	1090	15.7	Blue mud	dark bluish gray	„	very strongly c.
174	40 54	28 53	120	17.1	Shallow-water deposit	brownish gray	sandy and stony clay	loosely c.
175	40 48	27 59	1103	10.4	Blue mud	dark gray-brown	sandy clay	very strongly c.
184	38 10	22 33	850	39.4	Globigerina ooze	grayish brown	clay	„ „ „
189	37 44	15 58	1500-2000	20.3	Blue mud	„ „	sandy clay	„ „ „
201	39 10	9 35	16—9	45.2	Shallow-water deposit	reddish white	gravel	not coherent
213	40 14	0 54	75	27.4	„ „ „	grayish brown	sandy clay	strongly c.
214	39 39	0 39	500—415	28.7	Blue mud	„ „	clay	very strongly c.
217	38 01	1 48	ca. 2000	48.3	Globigerina ooze	brown	sandy clay	loosely c.
228	36 02	5 06 W	780	15.2	Blue mud	gray-brown	„ „	strongly c.
231	35 56	7 16	ca. 1000	22.3	„ „	grayish brown	clay	very strongly c.
234	38 10	9 20	920	28.7	„ „	gray-brown	stony clay	„ „ „

In regard to the terms used I have followed the usual system introduced by MURRAY in his well-known work on the "Challenger" Expedition, even if it possibly does not suit quite so well for inland seas. The boundary between shallow-water deposits and deep-sea deposits is, as usual, placed at 200 meters, and it is a general rule also for the open seas, that the more clayey deposits begin at this depth. For the Mediterranean we should expect beforehand, that this boundary would not be so natural; in an inland sea, like the Baltic, we are accustomed to find clayey sediments at a much smaller depth. The Mediterranean, however, so far as we can conclude from the available material, seems to agree in this regard with the large oceans. Of the 8 samples taken in depths less than 200 m., 6 are composed of quite loose soils, consisting mainly of fragments of calcareous shells, whilst only 2 (Nos. 140 and 213) are of clayey consistency and more coherent in the dry condition. It is not only the quantity of calcareous shells, however, which give the majority of these samples their coarse character; even after dissolving away the lime most of them would still appear as fairly coarse samples; it is obvious, on the whole, that the rocky coasts of the Mediterranean with the strong surf imply conditions which approach in most ways those of the great oceans. The boundary between blue mud and Globigerina ooze is as usual drawn at 30 % $CaCO_3$; in the Mediterranean, where it is very difficult on the whole, as will be shown later, to find any definite connection between the amount of clay on the one hand and the depth or distance from land on the other, it is likewise quite impossible, with our present knowledge, to indicate the distribution of these two kinds of bottom-soil. The four samples of blue mud from the Mediterranean (Nos. 126, 189, 214 and 228) lie widely separated from one another, as a consideration of the Chart will show, and were all taken fairly near to land. At no places in the Mediterranean has any definite decrease in the amount

of lime been noticed in the greatest depths, which might indicate that the bottom-soil was changing over to red clay; but depths of 4000 m., which are probably the highest point reached by this kind of soil, are only known here over a very small area. In the open oceans the boundary is probably considerably deeper as a rule, but in the sea between the Sunda Islands, which is perhaps the nearest comparison we can make with the Mediterranean in this regard, the calcium carbonate just begins to be more perfectly dissolved at 4000 m.; it would be of extreme interest, for the understanding of these conditions, to examine samples from corresponding deep parts of the Mediterranean and see how great the amount of lime is at these places.

The colour of the bottom-samples is on the whole very uniform; excepting the more divergent shallow-water deposits the samples from the Mediterranean are brown or grayish brown; only a single one (No. 134) is just as much gray as brown. In the Straits of Gibraltar and Atlantic on the one side and in the Sea of Marmora on the other, the few available samples are as a rule intermediate between gray and brown, and in the Black Sea (No. 172) there is nothing left of the brown; the colour is here dark bluish-gray. Bottom-samples from the Mediterranean are as a rule of a lightish tint, but this is not mentioned in the Table, as it is seen in them all.

It has been shown earlier on several occasions, that the clay which is first deposited on the sea-bottom, like that deposited by other geological activities, is most probably of a pure gray colour as a rule, and it is probable that the brown colour arises from a process of oxidation. This process, however, seems to be a very slow one, so that the deposits formed closer to land, where the sedimentation proceeds comparatively quickly, do not become oxidized before they are covered by later deposits and they can thus preserve their gray colour. This gray, or rather bluish colour, which has given rise to the name blue mud, might conceivably be due to a greater proportion of organic matter in these deposits, which might have a direct reducing action; but so far as one can see, there seems no reason why smaller quantities of organisms should be deposited further away from the coast than in its neighbourhood, so that this action has possibly no connection with the colour of the samples. From the fact also, that the Mediterranean samples are so distinctly brown, we might conclude that they are formed extremely slowly, just as we might expect indeed, if we consider the few rivers which flow out into this Sea. The fact, that the amount of calcium carbonate is not greater than about 50 % on the average, may thus simply be due to the relatively small quantity of organisms, which is deposited on the sea-bottom.

The consistency of the samples is indicated by the ordinary, petrographic terms as sand, clay etc. and no attention is paid here to whether the coarser particles are composed of shells, which is the case in most samples, or of mineral substances. The difference is of very little importance for the impression we obtain of the sample, whether from looking at it or feeling it. With regard to the relative quantities of the different sizes of grain in the samples, reference may be made to the analyses of the siftings given later.

In close connection with the consistency of the samples is their degree of coherency in the dry condition, which is given in the last column of the Table; there is no need to discuss this further.

The percentage of calcium carbonate in the samples has been determined by means of Scheibler's apparatus, which is quite accurate enough for this purpose, as an inaccuracy of 1—2 % is of no great consequence. It will be seen, that the true deep-sea samples from the Mediterranean contain amounts which vary from 20.3 to 67.0, on an average 44.3 % $CaCO_3$. If we take the eastern and western parts of the Mediterranean separately, we obtain averages for both which are in perfect agreement with the above. The samples of this Expedition are, however, too few to give a proper picture of the conditions, but from the Eastern Mediterranean we have a number of $CaCO_3$ determinations made by Windt and Berwerth, which may also be taken into consideration.

Windt and Berwerth have determined the amount of $CaCO_3$ in 47 samples in all and their results

vary from 11.36 to 86.63 with an average of 59.1 %. At the same time they have made use of NATTERER's very extensive, chemical analyses, overlooking the fact, that these were made on the fine washings and not on the whole sample, which makes a very great difference in regard to the amount of calcium carbonate. Since the coarser constituents consist almost entirely of shells, the fine washings are naturally very much poorer in lime than the whole sample. This is also displayed in several ways; for example, the averages obtained by WINDT and BERWERTH from their calculations of NATTERER's samples give only 48.1 % $CaCO_3$, which is a considerably lower value than obtained from WINDT and BERWERTH's own analyses; one locality (28° 42' 30" Lat. N. and 36° 31' 24" Long. E.) was examined by both, and WINDT and BERWERTH found 44.19, but NATTERER 30.46 % $CaCO_3$. I have also made a direct investigation into this relation by determining the amount of lime both in the sample as a whole and in its fine washings; the results for this sample (No. 132) were respectively 56.2 and 45.3 %.

WINDT and BERWERTH have drawn up tables to show, whether there was any connection between the amount of lime on the one side and the depth or distance from land on the other, but there does not appear to be any from these tables; in these, however, NATTERER's results were included, though as mentioned not comparable with WINDT and BERWERTH's; excluding these and inserting the results from the bottom-samples of the "Thor" we obtain the following Table.

Depth in m.	Per cent. $CaCO_3$	Depth in m.	Per cent. $CaCO_3$	Depth in m.	Per cent. $CaCO_3$	Depth in m.	Per cent. $CaCO_3$
13	98.5	1010	71.3	1765	62.9	2812	27.0
35	91.0	1090	58.6	1770	77.1	2860	41.5
75	27.4	1080	35.9	1870	39.4	3055	67.3
98	81.3	1227	56.7	1925	67.0	3120	50.9
112	22.0	1242	42.0	1969	77.2	3150	68.4
195	43.2	1260	63.7	2050	11.4	3150	48.0
240	48.4	1310	55.8	2090	35.3	3200	34.4
380	72.3	1510	80.0	2130	53.7	3280	67.5
410	37.6	1514	55.3	2165	69.2	3300	74.4
568	70.3	1600	48.5	2288	66.9	3320	51.4
615	67.2	1627	44.2	2352	54.6	3320	59.8
740	80.4	1630	79.1	2440	48.4	3580	51.5
820	53.9	1651	86.6	2490	39.9	3590	59.0
850	39.4	1688	75.8	2600	61.4	3591	61.8
915	52.6	1746	63.5	2636	67.6	3680	41.8
960	65.5	1650	64.5	2773	39.9	3700	74.5

There seems to be no relation here between the depth and amount of lime; for the sake of comparison I have collected the samples into groups for every 500 m. and calculated the average amount of lime in each of the groups, as can be seen from the following Table.

Depth in m.	Average percentage of $CaCO_3$
0—500	58.0
500—1000	61.2
1000—1500	54.9
1500—2000	64.5
2000—2500	47.3
2500—3000	47.5
3000—3500	58.0
3500—3700	57.7

It thus appears that, however we may arrange the results, we cannot find any interrelation between the two series, and the relation will be no better with the distance from land, as this factor stands on the whole in close connection with the depth. There must be some complicating cause at the back of this, as we cannot imagine that the amount of lime is absolutely uninfluenced by the depth and distance from land, since these two factors must be presumed to take part in the composition of the samples in practically all respects. We must rather believe, that various conditions connected with the changes in depth exercize their influence on the amount of lime, in such a way that they counterbalance or work against each other.

In his work on the "Challenger" Expedition MURRAY lays chief weight on the fact, that the water at great depths may contain more carbon dioxide and in consequence can more readily dissolve the

carbonate of lime, than it is able to do at less depth; he thus means on the whole, that the amount of lime should decrease with increasing depth, which seems indeed to agree with the samples of this Expedition. It is extremely probable, that this greater solubility may be of great importance, but it is just as certain, that the consequent decrease in the amount of lime is in many cases counterbalanced by the land materials being deposited in much smaller quantities further from land than nearer to it and consequently, if no other moments take part, that the amount of lime must always increase with increasing depth. This condition is also very apparent at places, as I have shown, for example, from the examination of the bottom-samples of the "Ingolf" Expedition, and in the Northern Atlantic we can draw regular curves round all land to show increasing amount of lime outwards. As we cannot assume, that the amount of sediment brought down from land is less in warmer regions, from which most of the samples of the "Challenger" came, than in the colder and just as little, that the solubility of carbonate of lime is essentially different in the two regions, there must be other factors which take part in the phenomenon. I cannot imagine any other than that the amount of the calcareous organisms which come to be deposited in shallower water must be many times larger in the warmer than in the colder regions, whereas the difference for the deeper water, where the temperature is almost uniform everywhere, is much less considerable. In the warmer seas we have in reality the condition, that the percentage of lime close to land is at places, e. g. near the outlet of rivers, nearly 0 and increases gradually outwards, whereas it elsewhere and more usually begins about 100 and then de-

No. of the sample	Below 0.05 mm.		0.05—0.5 mm.	0.5—1 mm.	1—2 mm.	2—5 mm.	Above 5 mm.
116	91.64	min.	0.01				
		org.	4.16	4.79	0.21	0.18	
		conc.	0.01				
			4.18	4.79	0.21	0.18	
126	99.56	min.	0.00	0.00			
		org.	0.33	0.08	0.02	0.01	
		conc.	0.00	0.00			
			0.33	0.08	0.02	0.01	
128	96.33	min.	0.00	0.00			
		org.	1.58	1.43	0.33	0.31	
		conc.	0.01	0.01			
			1.59	1.44	0.33	0.31	
131	92.88	min.	0.02	0.00			
		org.	3.73	2.30	0.40	0.52	0.14
		conc.	0.01	0.00			
			3.76	2.30	0.40	0.52	0.14
132	88.51	min.	0.12				
		org.	6.24	2.59	1.04	1.26	0.24
		conc.	0.00				
			6.36	2.59	1.04	1.26	0.24
133	95.60	min.	0.03	0.00			
		org.	2.70	1.17	0.18	0.17	0.15
		conc.	0.00	0.00			
			2.73	1.17	0.18	0.17	0.15
134	97.98	min.	0.03	0.00			
		org.	1.48	0.33	0.09	0.09	
		conc.	0.00				
			1.51	0.33	0.09	0.09	
137	55.51	min.	2.35				
		org.	22.04	14.14	1.63	0.40	0.33
		conc.	3.53	0.07			
			27.92	14.21	1.63	0.40	0.33
138	62.51	min.	0.18	0.00			
		org.	20.61	12.77	3.10	0.75	0.03
		conc.	0.05	0.00			
			20.84	12.77	3.10	0.75	0.03
140	99.01	min.	0.13				
		org.	0.62	0.02	0.00	0.21	
		conc.	0.01				
			0.76	0.02	0.00	0.21	
142	7.56	min.	7.10	0.25	0.04		
		org.	30.28	29.03	17.40	6.25	1.72
		conc.	0.37				
			37.75	29.28	17.44	6.25	1.72
145	61.14	min.	0.13	0.00			
		org.	4.70	4.49	3.85	3.65	1.02
		conc.	0.94	2.24	7.70	10.14	
			5.77	6.73	11.55	13.79	1.02
147	80.17	min.	1.02	0.00			
		org.	6.14	2.33	0.29	0.21	
		conc.	2.16	2.33	2.60	1.85	0.90
			9.32	4.66	2.89	2.06	0.90

No. of the sample	Below 0.05 mm.		0.05—0.5 mm.	0.5—1 mm.	1—2 mm.	2—5 mm.	Above 5 mm.
148	72.16	min.	1.11	0.00			
		org.	4.12	0.60	0.29	0.25	0.04
		conc.	0.65	0.30	0.22	0.26	
			5.88	0.90	0.51	0.51	0.04
150	0.00	min.	0.74				
		org.	14.14	50.07	26.08	8.97	
		conc.					
			14.88	50.07	26.08	8.97	
153	0.00	min.	0.00	0.30			
		org.	0.88	60.06	37.72	1.04	
		conc.	0.00				
			0.88	60.36	37.72	1.04	
160	87.71	min.	0.51	0.01			
		org.	1.05	0.26	0.23	0.23	
		conc.	0.00				
			1.56	0.27	0.23	0.23	
163	99.69	min.	0.01	0.00			
		org.	0.29	0.01	0.00		
		conc.	0.00				
			0.30	0.01	0.00		
172	91.51	min.	5.27	0.01	0.00		
		org.	2.95	0.00	0.01	0.00	
		conc.	0.28	0.03	0.02	0.02	
			8.50	0.04	0.03	0.02	
174	40.43	min.	24.97	1.52	0.14	0.07	
		org.	8.81	1.32	0.81	0.54	0.31
		conc.	0.51	0.41	0.02	0.00	
			34.29	3.25	0.97	0.61	0.31
184	99.95	min.	0.00	0.00			
		org.	0.04	0.01	0.00		
		conc.	0.00				
			0.04	0.01	0.00		
189	99.18	min.	0.51	0.02			
		org.	0.31	0.03	0.02	0.02	
		conc.	0.00	0.01			
			0.82	0.06	0.02	0.02	
201	0.00	min.	28.91	21.37	0.26		
		org.	2.55	5.55	25.36	16.00	
		conc.	0.00				
			31.46	26.92	25.62	16.00	
213	98.04	min.	0.71	0.01			
		org.	0.97	0.12	0.07	0.04	
		conc.	0.04				
			1.72	0.13	0.07	0.04	
214	98.64	min.	0.31	0.00	0.00		
		org.	0.92	0.08	0.02	0.01	
		conc.	0.02				
			1.25	0.08	0.02	0.01	
217	85.12	min.	0.01	0.00			
		org.	6.17	8.53	0.09	0.08	
		conc.	0.00				
			6.18	8.53	0.09	0.08	

creases naturally with the distance from land. In regard to the quantity of calcareous organisms which are deposited close to land, the Mediterranean comes midway between the Northern Atlantic and the tropical seas, and the result of the different cooperating factors is, therefore, as we have seen, that the amount of lime becomes on the whole remarkably uniform over the whole region. The coast of North Africa presents the greatest contrasts; in its neighbourhood we find the smallest percentages of lime discovered anywhere, namely NATTERER's results 4.77 and 5.59 north of the Mouth of the Nile, and on the other hand we find in Syrtis Major and on the coast of Barka the largest amounts of lime observed in the Mediterranean (respectively 91.0 and 98.3 %).

In order to give a better picture of the composition of the samples than is possible by a simple description of their consistency, I have washed and sifted most of them. I have not found it necessary to make any further separation of the constituents below 0.05 mm., as in all the samples, even in the components from 0.05 to 0.5 mm., there were extremely large quantities of clay, which had to be split up by repeated mechanical treatment before getting down to the grains, which really belonged to this division, in the pure condition. As such treatment could not be given to the smaller sizes of grain, a determination of the quantity of these has no value whatsoever, since we cannot determine the proportion between the single components, as they were originally deposited, but obtain mainly a picture of, how strongly coherent the clay is at the different places.

The Table shows, for all sizes of grain except the smallest, the percentual

amounts of the three main constituents in the samples, namely, primary minerals, organisms and secondary minerals. The results given can only be regarded as approximate, as they have been obtained as a rule from the enumeration of a portion of the grains. The three groups are distinguished in the Table by respectively min., org. and conc. (= concretions).

No. of the sample	Below 0.05 mm.		0.05—0.5 mm.	0.5—1 mm.	1—2 mm.	2—5 mm.	Above 5 mm.
228	97.78	min.	0.39	0.00			
		org.	1.10	0.51	0.02	0.01	0.15
		conc.	0.04				
			1.53	0.51	0.02	0.01	0.15

III. Mineral constituents of the samples.

The quantity of the mineral constituents for the different sizes of grain is shown in the foregoing Table. With regard to the smallest size of grain, the percentage of the mineral constituents in it corresponds approximately to that in the whole sample and is thus approximately the percentage which remains after the carbonate of lime is removed. It is possible, however, that a quantity of concretions is present in this group, but the amount has not been exactly determined.

It may be said on the whole, that the amount of sand in the samples is very small. For the sake of comparison it is necessary to distinguish between the different sorts of these; in the true deep-water samples (blue mud and Globigerina ooze) of the Mediterranean there is on an average 0.25 % of the constituents between 0.05 and 0.5 mm., whereas the shallow-water deposits have 5.51 %. Of the constituents over 0.5 mm. the percentual amounts for the two kinds of samples are even only 0.00 and 3.18. For the shallow-water deposits we cannot make comparisons with other samples, as this kind of bottom-soil must always, in the nature of the case, vary enormously in consistency according as the sample is taken near the shore or a little farther out. For the deep-water samples we may compare the results with those from the "Ingolf" Expedition and we find, that the same two sizes of grain compose respectively 16.95 and 2.84 % in the very numerous samples investigated. Even if we only include the "Ingolf" Expedition's samples of Globigerina ooze, the results for this are 6.49 and 0.90 and the samples from the Northern Atlantic thus contain 30 times as much sand (over 0.05 mm.) as those of the Mediterranean, although the amount of lime, which is very usually taken as the standard for the pelagic nature of the sample, is very nearly the same at both places. It is thus the material brought down from the land, which is itself different in nature at the two places, and what is characteristic for the Mediterranean is just, that the amount of sand is so extremely small in proportion to the clay. The reason of this is difficult to find; the fact that the sea-bottom in the North Atlantic obtains a part of its material from icebergs, cannot be of any great importance, as samples I have examined from the Sunda Islands are essentially the same in this regard as those from the Atlantic; nor is there any reason to believe, that the types of rock on land are of an essentially different nature in the Mediterranean countries from those at other places. The fact, that but little sediment is carried out on the whole into the Mediterranean, cannot explain either the differences in the nature of this sediment. It may be assumed, that there are no very strong currents in the Mediterranean which can carry the material away from the land; but this seems to be counterbalanced by the Mediterranean samples having been taken on the whole at a very short distance from land.

With regard to the nature of the mineral constituents of the samples, these are on the whole very uniform. We should expect beforehand, that the volcanic minerals would be much in evidence, but in reality they are of very little importance. Volcanic ash has only been found with certainty in three of the samples. In No. 189, close to the south point of Calabria, ca. 50 % of the sand is composed of black ash, the single grains of which are usually quite opaque under the microscope; but some of them consist distinctly of brown glass. That they must have come from Etna is evident, not only from the locality but also from the fact, that they greatly resemble the very black ash of this mountain. The samples of Etna ash, which I have seen, certainly contain considerably more transparent glass, but the samples from a volcano may vary greatly in different eruptions. In the sample No. 128, which was taken in the Tyrrhenian Sea, 0.01 % of the sand consists of a fairly light glass-ash, of the same nature as the ash so often expelled from Vesuvius. As none of the other samples were taken in greater proximity to Vesuvius, it is impossible to say anything further with regard to the part played by Vesuvius ash in the sea-bottom. Lastly, reference may be made to the sample No. 163, from the coast of Asia Minor, in which 0.02 % of the sand consists of glass-ash, which has possibly come from Santorin; here also it is a pity that there are no samples from nearer at hand. As the samples from the Mediterranean are so extremely poor in mineral constituents similar in size to sand, it is all the more remarkable, that the volcanic ash is not present in greater proportion. It should be mentioned, however, that WINDT and BERWERTH record pumice from a sample taken close to the south point of Greece and volcanic ash from three samples from the Levant, but nothing is said as to the amount of these constituents, which may probably have been very small.

If we exclude the volcanic ash, the sand is otherwise, as we should expect, very uniform in mineralogical regards and consists of ordinary quartz grains with larger or smaller quantities of felspar. There is a strikingly small amount of the latter in the sample No. 137, taken close to the coast of Tunis; here the felspar only amounts to about 1 % of the sand, a smaller proportion than I have ever found earlier. On the other hand, the sample No. 201, taken close to the coast of Sardinia, has almost just as much felspar as quartz, which is also extremely rare. In the sample No. 160 (at Rhodes) the greater part of the sand consisted of indeterminable, semitransparent grains, probably fragments of one or other dense kind of rock.

IV. Organic constituents of the samples.

As already mentioned, the organisms play an extremely great part in the composition of the samples and relatively most in the coarser constituents, which consist almost exclusively of calcareous shells. As there are extremely few siliceous organisms, the quantity of $CaCO_3$ gives very approximately the amount of the organic constituents.

As the calcareous organisms are of so great importance in the whole appearance of the sample, the nature of the larger sorts is indicated in the Table below. The order in which the constituents are given, also indicates the quantitative proportions between them; if one group is far in excess of the others in quantity, it is indicated by interspaced letters.

Shells found in the samples.

It will be seen from the Table, that the Foraminifera, just as we should expect, are of very little importance among the constituents over 1 mm., whereas they are predominant in the smaller group. The large part taken by the Pteropoda in the larger constituents is very striking; yet there is a wide difference between the different kinds of samples in this regard. In the 14 samples of Globigerina ooze we find, that the Pteropoda form the main constituent in 11 of them and in 6 are far in excess of the others or even the only constituent. It is only in two samples, Nos. 133 and 134 south of Sardinia, that they give way to other kinds of calcareous shells and in one sample, No. 184 in the Gulf of Corinth, they are quite wanting. The samples of blue mud are very variable; on the other hand, it is common to all the samples of shallow-water deposits that Pteropoda are quite wanting in them. But the composition of these is very varied; those taken nearest to the coast mainly contain rolled fragments of shells of an indeterminable nature. The sample from the Black Sea (No. 172) and that from the Sea of Marmora (No. 174) are characterized by containing Bivalves exclusively or predominantly.

Among the constituents between 0.05 and 0.5 the Foraminifera are even more predominant than in the next larger group, and among them again Globigerina is in excess of all the other forms.

No. of the sample	above 1 mm.	0.5—1 mm.
116	Pteropoda. Opercula of Gastropoda.	Foraminifera. Pteropoda.
126	Foraminifera. Pteropoda. Other Gastropoda. Bivalves.	Foraminifera. Fragments of various other shells.
128	Pteropoda. Other Gastropoda. Opercula of Gastropoda. Bivalves.	Pteropoda. Foraminifera, etc.
131	Pteropoda. Other Gastropoda. Opercula of Gastropoda. Bivalves. Foraminifera. Bryozoa.	Foraminifera. The same constituents as in previous column.
132	Pteropoda. Opercula of Gastropoda. Foraminifera. Bivalves. Other Gastropoda.	Foraminifera. Pteropoda etc.
133	Corals. Pteropoda. Opercula of Gastropoda. Foraminifera.	Foraminifera. Pteropoda etc.
134	Other Gastropoda. Opercula of Gastropoda. Foraminifera. Pteropoda. Bivalves.	Foraminifera etc.
137	Bryozoa. Bivalves. Other Gastropoda. Echinids.	Foraminifera etc.
138	Pteropoda. Other Gastropoda. Crustacea. Bivalves. Foraminifera.	Foraminifera etc.
140	Bivalves. Other Gastropoda.	Foraminifera. Bivalves. Other Gastropoda.
142	Indeterminable shells of irregular rounded form. Bivalves. Other Gastropoda.	The same constituents. Foraminifera.
145	Pteropoda.	Pteropoda. Foraminifera.
147	Pteropoda. Foraminifera. Bivalves. Opercula of Gastropoda. Other Gastropoda.	Foraminifera. Pteropoda.
148	Pteropoda. Bivalves. Foraminifera. Other Gastropoda. Bryozoa.	Foraminifera. Pteropoda etc.
150	Rounded fragments of shells. Bivalves. Other Gastropoda. Opercula of Gastropoda.	Rounded fragments of shells. Foraminifera.
153	Rounded fragments of shells. Spines of Echinids. Bivalves. Other Gastropoda. Bryozoa. Foraminifera.	Almost the same constituents as in previous column.
160	Pteropoda. Opercula of Gastopoda.	Foraminifera. Pteropoda.
163	Pteropoda.	Pteropoda. Foraminifera.

No. of the sample	above 1 mm.	0.5—1 mm.
172	Bivalves.	Opercula of Gastropoda. Pteropoda. Foraminifera.
174	Bivalves. Other Gastropoda. Echinids.	The same. Foraminifera.
184	Indeterminable fragments. Opercula of Gastropoda. Spines of Echinids.	The same. Foraminifera.
189	Pteropoda. Opercula of Gastropoda.	Pteropoda. Foraminifera.
201	Calcareous algæ. Bryozoa. Bivalves. Other Gastropoda.	The same. Foraminifera.
213	Other Gastropoda. Bivalves. Echinids. Bryozoa.	The same. Foraminifera.
214	Bivalves. Foraminifera. Opercula of Gastropoda.	Foraminifera. Bivalves.
217	Pteropoda. Opercula of Gastropoda. Bivalves.	Foraminifera. Pteropoda etc.
228	Bivalves. Other Gastropoda. Opercula of Gastropoda. Foraminifera.	Foraminifera etc.

The other calcareous forms in this group are mostly indeterminable fragments of larger shells. In the smallest group (less than 0.05 mm.) Coccoliths predominate; there is no reason, however, to discuss these organisms in detail here, as they are in no way distinct from the common forms found elsewhere.

Of siliceous organisms there are surprisingly few in the Mediterranean, and I cannot remember any other region where they are so unimportant by comparison with the calcareous organisms. To obtain an approximate idea of the quantity of them present in the group between 0.05 and 0.5 mm., I have counted all that were found in an entire sand preparation and then estimated approximately, how many sand grains were in the same preparation. In this way we have the quantity of siliceous organisms in relation to the mineral constituents, and from this again we can estimate the proportion to the total constituents. The result is, that the siliceous organisms only amount on the average to about 0.0005 per cent, thus 5 millionths of this group. Among the larger grains there are no siliceous organisms at all and even in the smallest size of grain there are exceedingly few. The organisms found are Radiolaria and sponge spicula, very much to the same amount; I have not been able to detect a single diatom in any of the samples.

Other organic remains than lime and siliceous shells do not occur with exception of some few sand-tube Foraminifera in sample No. 228.

V. Concretionary constituents of the samples.

Of concretionary or secondary minerals there is a relatively large number in the Mediterranean, even though they are naturally much rarer than the two other kinds of constituents. Deposits of the following substances were found: pyrite, glauconite, gypsum, calcite and dolomite.

Pyrite has only been found in some few of the samples and as a rule only in quite small quantity. In the Mediterranean it occurs in Nos. 138 and 140 at the east point of Sicily, where 1—2 % of the uncalcified constituents of the sand consisted of pyrite. In the Sea of Marmora it occurs in small quantity in No. 174; it occurs in specially large quantity in the Black Sea, amounting to 5 % of the sand

in sample No. 172, where also it composes the principal mass of the comparatively few, larger constituents. It is probably also present, in very finely divided form, in the finer constituents, thus giving rise to the dark colour of the sample. The sea-water of the Black Sea, at least near the bottom, must contain many reducing organic constituents which prevent the sulphuretted hydrogen formed by the decomposition of the organisms from being transformed to sulphuric acid, which we may believe takes place where the sea-water contains sufficient oxygen. Where the iron compounds come from, which go to form the pyrites, is not easy to say; at the places where there is a sufficient amount of oxygen, the iron is usually deposited in the form of glauconite. The pyrite in the sample No. 172 has essentially the form of rounded grains with a somewhat irregular, finely gritty surface, probably due to the presence of quite small crystals. In the samples from the Mediterranean the pyrite is not so typically developed and is possibly not formed there on the sea-bottom; it may come from the land. This view is also supported by the fact, that the Mediterranean water must be considered on the whole to be rich in oxygen; further, the pyrite in these last samples occurs together with glauconite, which would be rather inexplicable, if the pyrite were secondary. The occurrence together of the two substances seems also, so far as I can judge, very rare in other parts of the world.

The glauconite occurs in the samples in far greater quantity than the pyrite. It occurs, as is usually the case, in the sandy constituents (0.05—0.5 mm.); in the coarser sizes of grain it is only present in small quantity. It is certainly always present as the filling of Foraminifera and thus only appears in the sand after the lime has been dissolved. To show its distribution, I have drawn up the following Table of the amount of glauconite in the constituents from 0.05 to 0.5 mm., on the one hand in proportion to the mineral (primary) constituents of the same size of grain (I) and on the other in proportion to the total quantity of this size of grain (II). As we do not know the proportion of the glauconite among the finest constituents, we cannot obtain any better value for the quantity in the samples as a whole. The samples not mentioned in the Table do not contain glauconite. The percentages are only approximate.

In the following we shall only consider the percentages under II, which give the best picture of the amount of glauconite in the samples. It appears that the average quantity is 0.11 for the 14 samples of Globigerina ooze in the Mediterranean, and 1.40 for the 4 samples of blue mud. The shallow-water deposits must be divided into two groups; the three gravelly samples Nos. 150, 153 and 201 contain no trace of glauconite, the other four, which are more sandy and clayey, contain 4.20 % on an average. It appears therefore on the whole, that excluding the samples nearest the land the glauconite decreases as a whole with the depth. In the deepest of all the samples, No. 160 at 3200 m., it is not present, but in the next deepest, No. 116 of 2860 m., we find already 0.12 %. In samples taken at greater depths than 1000 m., however, the quantities found are but small in all cases, and this also agrees with what we know from other places. The sample from the Sea of Marmora (No. 174) is extremely rich in glauconite, whereas the one from the Black Sea (No. 172) has none at all.

No. of the sample	Percentage of glauconite	
	I	II
116	30	0.12
126	2	0.02
128	50	0.25
131	30	0.21
132	2	0.09
133	10	0.10
134	10	0.22
137	60	12.64
138	20	0.55
140	5	0.94
142	5	0.99
145	2	0.04
174	10	7.43
213	5	2.10
214	5	1.33
217	2	0.00
228	10	2.84

Gypsum, which is elsewhere rare as a constituent of the sea-bottom, is found in a number of the samples in the form of well-developed crystals, which are always $^1/_2$—1 mm. in diameter and on the whole extremely uniform in the different samples; except that in some cases they may be quite fresh, clear and transparent, whereas in other samples they are opaque and porcelain-like, so that under the microscope they appear to contain the original gypsum substance in very small quantity. They have a rhombic form with the surfaces usual for the mineral, namely (010), (110) and (111). The colour is

faintly yellowish and the surfaces are not specially well-developed. The quantity of these crystals is in no case so great, that they can be said to compose any essential part of the sample. They occur altogether in five of the samples, in greatest quantity in Nos. 126, 128 and 131 in the Tyrrhenian Sea, in small numbers in No. 138 west of Sicily and in No. 148 in Sidra Bay. It is difficult to give any reason for this deposition of the gypsum; it can only be formed, one would think, in water rich in oxygen, where sulphuric acid may be formed from the oxidation of sulphuretted hydrogen. That the gypsum crystals may have come from the land, seems to be excluded, for the reason alone, that there are, at least in the samples 126 and 128, far more of these than of certain terrigenous constituents of the same size of grain.

Carbonate of lime is the material which is present in greatest quantity as concretions in the samples. In many cases it is deposited in such small quantities, that its only effect is to make the sample a little more coherent than it otherwise would be, but as a rule it is present in the form of definitely formed, very compact masses, which however always enclose a portion of the original constituents of the sample, especially Foraminifera and quartz grains. The form is quite characteristic, the concretions being almost always sharp-edged with irregular boundaries, and it looks as a rule as if they were fragments of a larger, coherent mass. That they cannot have been formed in this way, however, may be concluded from the fact, that the Pteropoda and other organisms, which occur together with them, are in most cases in a perfectly well-preserved condition; the irregular form is most probably due to the lime merely forming the binding-material for the other constituents, which may sometimes be of a coarse nature. Coherent crusts of lime were certainly found by the "Pola" Expedition to have a wide distribution in the Eastern Mediterranean, but there is no trace of these in the samples of the present Expedition. The largest quantity of these concretions was found in the samples Nos. 145, 147 and 148 in Sidra Bay, where, as will be seen from the Table on p. 261, they even composed a very essential part of the whole sample. In thin sections they consist of an extremely fine ground-mass, in which as mentioned we find Foraminifera, sand-grains etc. and further, as new formations, very small calcite and dolomite crystals. The former appear as very regular stellate crystals, consisting of pointed rhombohedra (probably $(02\bar{2}1)$) arranged radially in all directions. The dolomite on the other hand has the form of single crystals of the fundamental rhombohedron $(10\bar{1}1)$. In the remaining samples the lime concretions are present in smaller quantities and usually appear as slightly indurated bottom-soil, for which reason they shall not be discussed further.

Dolomite. This mineral appears, as mentioned, in the form of small crystals in the lime concretions; similar crystals are also common however in the samples outside these. The form is everywhere the same. The size is never over 0.5 mm., so that they are found mainly in the sand preparations; in a few cases I have noticed, that they also occur among the finer constituents. As the preparations in which I have determined the dolomite, came from material which had been treated beforehand with hydrochloric acid, confusion with calcite is excluded; that no siderite is present, I have determined, at least in several of the samples, by heating the grains. To give a view over the quantity of dolomite in the different samples I have drawn up the following Table, in which the numbers I and II mean the same as in the Table p. 267.

No. of the sample	Percentage of dolomite	
	I	II
116	0.5	0.002
131	0.5	0.004
132	0.5	0.009
138	0.1	0.001
147	0.1	0.01
148	0.1	0.02
153	40	0.24
160	0.1	0.03
163	0.1	0.004
172	0.1	0.07
184	2	0.08
189	0.01	0.006
213	1	0.44
214	5	1.33
217	2	0.002
228	3	0.85

It is difficult to construct any rule for the distribution of the dolomite from these figures; the largest quantities occur in samples which were taken close to the coast, thus in Nos. 213 and 214 on the east coast of Spain, and in No. 228 in the Straits at Gibraltar. Further, there are large quantities in No. 153, which is one of the samples taken nearest the land, namely at a depth of 13 m. on the north coast

of Barka. Fairly large quantities are also present in the sample No. 184 from the Gulf of Corinth and No. 172 in the Sidra Sea. On the other hand, there is a number of samples taken near the land, which do not contain dolomite, and the only thing that can be said generally is, that the quantity of dolomite decreases on the whole with increasing depth and distance from land. Whether the distribution of the calcareous organisms which contain magnesia stands in any definite relation to the quantity of dolomite, it is impossible to say.

VI. Summary.

From what has been said in the foregoing an impression will have been gained as to the nature of the bottom-deposits of the Mediterranean. By way of summary I may mention the following series of characteristics for the typical, deep-water soils from the Mediterranean.

The colour is light-brownish.

The consistency is sandy-clayey.

The amount of lime varies round about 50 % and is not appreciably dependent on the depth or distance from land.

Of the inorganic constituents the clay is much in excess of the sand, a condition we do not meet with in any other region under approximately similar conditions.

Volcanic constituents are much less in evidence than we should expect beforehand.

The coarser constituents in the samples are almost exclusively calcareous shells and among these the Pteropoda are remarkably prominent; among the smaller calcareous shells the Foraminifera and Coccoliths are as usual predominant.

Siliceous organisms occur in extremely small quantity.

Secondary minerals occur in fairly large number; arranged in the order of their quantitative occurrence, they are calcite, glauconite, dolomite, pyrite and gypsum.

STATIONS WHERE BOTTOM-SAMPLES WERE COLLECTED.

The fat numbers represent the percentage of calcium carbonate in the samples.

List of Papers resulting in whole or in part from the Cruises of the Danish Research-Steamer "Thor" in the Atlantic and Mediterranean.

1. Hydrography.

J. P. JACOBSEN, in Schmidt, Nielsen og Jacobsen: Fra den danske oceanografiske Expedition til Middelhavet i Vinteren 1908—1909. (Geografisk Tidsskrift, 20, H. VI, København 1910).

MARTIN KNUDSEN: Danish Hydrographical Investigations at the Faroe Islands in the Spring of 1910. (Meddelelser fra Kommissionen for Havundersøgelser, Serie: Hydrografi, II, No. 1, København 1911).

J. N. NIELSEN: Hydrography of the Waters by the Faroe Islands and Iceland during the cruises of the Danish research-steamer "Thor" in the summer 1903 (ibid. I, No. 4, 1904).

— Contributions to the Hydrography of the Waters north of Iceland (ibid. I, No. 7, 1905).

— Contribution to the Hydrography of the north-eastern part of the Atlantic Ocean (ibid. I, No. 9, 1907).

— Contribution to the understanding of the currents in the northern part of the Atlantic Ocean (ibid. I, No. 11, 1908).

— in Schmidt, Nielsen og Jacobsen: Fra den danske oceanografiske Expedition til Middelhavet i Vinteren 1908—1909 (Geografisk Tidsskrift, 20, H. VI., København 1910).

— Sur les températures des grandes profondeurs particulièrement dans la Méditerranée, Note préliminaire, (Bulletin de l'Institut Océanographique, No. 209, Monaco 1911).

Numerous observations, sections etc. from the "Thor" Expeditions in the Atlantic have been published in: Bulletin Hydrographique du Conseil Permanent International pour l'Exploration de la Mer, København 1902 and following years.

2. Biology.

J. H. OSTENFELD: *Thorosphaera*, eine neue Gattung der Coccolithophoriden (Berichte der deutschen Botanischen Gesellschaft, Bd. 28, Berlin 1910).

OVE PAULSEN: Plankton-Investigations in the Waters round Iceland in 1903 (Meddelelser fra Kommissionen for Havundersøgelser, Serie: Plankton, I, No. 1, København 1904).

— On some Peridineae and Plankton Diatoms (ibid. I, No. 3, 1905).

OVE PAULSEN: Studies on the biology of *Calanus finmarchicus* in the waters round Iceland (ibid. I, No. 4, 1906).

— Plankton Investigations in the Waters round Iceland and in the North Atlantic in 1904 (ibid. I, No, 8, 1909).

— The plankton on a submarine bank (in Biologiske Arbejder tilegnede Eug. Warming d. 3. Nov. 1911, København 1911).

C. G. JOH. PETERSEN: On the Larval and Postlarval Stages of the Long Rough Dab and the Genus *Pleuronectes* (Meddelelser fra Kommissionen for Havundersøgelser, Serie: Fiskeri, I, No. 1, København 1904).

— Larval Eels (*Leptocephalus brevirostris*) of the Atlantic Coasts of Europe (ibid. I, No. 5, 1905).

— On the young stages of the Genus *Zeugopterus* (Report of the Danish Biological Station; XII, København 1905).

— On the Larval and Post-Larval Stages of some *Pleuronectidae (Pleuronectes, Zeugopterus)* (Meddelelser fra Kommissionen for Havundersøgelser, Serie: Fiskeri, II, No. 1, København 1906).

— On the Larval and Postlarval Stages of some *Pleuronectidae (Zeugopterus, Arnoglossus, Solea)* (ibid. III, No. 1, 1909).

JOHS. SCHMIDT: Fiskeriundersøgelser ved Island og Færøerne i Sommeren 1903 (Skrifter udgivne af Kommissionen for Havundersøgelser, No. 1, København 1904).

— On Pelagic Post-Larval Halibut (*Hippoglossus vulgaris* Flem. and *H. hippoglossoïdes* [Walb.]) (Meddelelser fra Kommissionen for Havundersøgelser, Serie: Fiskeri, I, No. 3, København 1904).

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— On the Larval and Post-Larval Stages of the Torsk (*Brosmius brosme* [Ascan.]) (ibid. I, No. 8, 1905).

— The Pelagic Post-Larval Stages of the Atlantic Species of *Gadus*, Part II (ibid. II, No. 2, 1906).

— On the Pelagic Post-Larval Stages of the Lings (*Molva molva* [Linné] and *Molva byrkelange* [Walb.]) (ibid. II, No. 3, 1906).

— On the Larval and Post-Larval Development of the Argentines (*Argentina silus* [Ascan.] and *Argentina sphyræna* Linné, with notes on *Mallotus villosus* [O. F. Müll.]) (ibid. II, No. 4, 1906).

JOHS. SCHMIDT: Contribution to the Life-History of the Eel (*Anguilla vulgaris* Turt.) (Rapports et Procès-Verbaux du Conseil International pour l'Exploration de la Mer, Vol. V, No. 4, København 1906).

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— On the Post-Larval Development of the Hake (*Merluccius vulgaris* Flem.) (ibid. II, No. 7, 1907).

— On the Post-Larval Development of some North Atlantic Gadoids (*Raniceps raninus* [Linné] and *Molva elongata* [Risso]) (ibid. II, No. 8, 1907).

— On the Post-Larval Stages of the John Dory (*Zeus faber* L.) and some other Acanthopterygian Fishes (ibid. II, No. 9, 1908).

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— On the Distribution of the Fresh-Water Eels (*Anguilla*) throughout the World, I. Atlantic Ocean and Adjacent Regions (ibid. III, No. 7, 1909).

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JOHS. SCHMIDT: Exposé sommaire des travaux de l'expédition océanographipue danoise dans la Méditerranée (1908—1909) (La Géographie, XXI, 2, Paris 1910).

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